

Bringing ‘Money’ Back in Monetary Models of Exchange Rate

By

Soumya Suvra Bhadury

Submitted to the graduate degree program in the Department of Economics and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Chairperson, William A. Barnett

Shu Wu

John Keating

Prakash Shenoy

Ryan Mattson

Date Defended: May 03, 2016.

The Dissertation Committee for Soumya Suvra Bhadury
certifies that this is the approved version of the following dissertation:

Bringing ‘Money’ Back in Monetary Models of Exchange Rate

Chairperson, William A. Barnett

Date approved: May 03, 2016

Abstract

Money overtime has been deemphasized from most of the open-economy macroeconomic models of exchange rate. The primary reason being the growing instability of money demand due to the rapid pace of the financial innovation and the velocity slowdown post 1980s. As money began to get deemphasized, interest rate alone became the monetary policy instrument. However the identification of the monetary policy requires the knowledge of both money supply and the money demand. In other words, interaction between the Central Bank's reaction to economic condition and the private sector's response to the policy action is crucial to the correct monetary policy identification, better prediction of the equilibrium quantity of the money and future rate of interest. Therefore attempts have been made to incorporate monetary aggregates back in the monetary models of the exchange rate determination. Additionally, a superior monetary measure, the aggregation-theoretic Divisia monetary aggregate has been introduced. Divisia money provides an index of 'monetary services' which captures the traditional transaction motive for holding money i.e. money demand.

Exchange Rate Overshooting in Small Open Economies: A Reassessment in a Monetary Framework- There has been a remarkable drop in the commodity prices and currency weakening for all the resource reliant economies since mid-2014. Rethinking on the central bank's monetary policy and reassessing the response of the exchange rate to policies is an active area of research. In the words of Kenneth Rogoff, "If one is in a pinch and needs a quick response to a question about how monetary policy might affect the exchange rate, most of us will still want to check any answer

against Dornbusch's model."¹ Surprisingly studies on monetary policies have found exchange rate effects that are mostly inconsistent with Dornbusch's overshooting hypothesis. Bjornland (2009) finds evidence of exchange rate overshooting by using identification restrictions that acknowledge simultaneity between monetary policy and exchange rate. However, the correct way of identifying monetary policy requires meticulously capturing the central bank's reaction to economic condition and at the same time private sector's response to policy action. This calls for introduction of 'monetary' aggregates back in the monetary model of exchange rate determination. Motivated by the Bjornland's result, this paper rediscovers the validity of Dornbusch Overshooting hypothesis for Australia, Canada, New Zealand and Sweden. More specifically, a contractionary monetary policy shock leads to exchange rate overshooting as predicted by Dornbusch. The exchange rate appreciates significantly on impact to a monetary policy shock as shown by the impulse response functions and thereafter depreciates. Also the variance decomposition results show that money demand and money supply shocks explain a significant portion of exchange rate fluctuations vis-a-vis Bjornland's original model.

An SVAR Approach to Evaluation of Monetary Policy in India: Solution to the Exchange Rate Puzzles in an Open Economy- Following the exchange-rate paper by Kim and Roubini (2000), the questions on monetary policy, exchange rate delayed overshooting, the inflationary puzzle, and the weak monetary transmission mechanism are revisited; but this is done so for the open Indian economy. A superior monetary measure, the aggregation-theoretic Divisia monetary aggregate is

¹ At the Second Annual IMF Research Conference, Mundell-Fleming lecture by Kenneth Rogoff, November 30, 2001. (Revised January 22, 2002)

incorporated in the model. The paper confirms the efficacy of the Kim and Roubini (2000) contemporaneous restriction, customized for the Indian economy, especially when compared with recursive structure, which is damaged by the price puzzle and the exchange rate puzzle. The importance of incorporating correctly measured money into the exchange rate model is illustrated, when compared among the models with no-money, simple-sum monetary measures, and Divisia monetary measures. The results are confirmed in terms of impulse response, variance decomposition analysis, and out-of-sample forecasting. In addition, a flip-flop variance decomposition analysis is done that suggests two important phenomena in the Indian economy: (i) the existence of a weak link between the nominal-policy variable and real-economic activity, and (ii) the use of inflation-targeting as a primary goal of the Indian monetary authority. These two main results are robust, holding across different time period, dissimilar monetary aggregates, and diverse exogenous model designs.

Divisia monetary model of exchange rate determination: A Multi country Analysis- There was a breakdown in the stability of money demand after the mid-1970s, an era characterized by financial liberalization and financial innovations. Therefore it simply became convenient to do away with the monetary aggregates and consider interest rate as the sole monetary policy variable. However it will be misleading to measure the impact of monetary policy and thereby rightly track the monetary policy transmission mechanism with the interest rates alone (when the rates are already stuck near zero) especially post 2008-crisis. Also any model that explicitly capture the role of ‘money’ can aid the central bank to track the money demand behavior of the private agent. This is crucial to monetary policy identification and measuring the impact of monetary policy on macroeconomic variables. Divisia money provides an index of ‘monetary services’ which captures the traditional transaction motive for holding money i.e. money demand. A modified Wald test criterion suggested by Toda-Yamamoto is taken up in evaluating the information content of the Divisia monetary aggregate along

with the alternative monetary policy indicators. The findings challenge the traditional view that short-term/ immediate rate of interest have better predictive power on the exchange rate than the alternate monetary indicators.

Subsequently Divisia monetary aggregate has been used in the monetary models of exchange rate and compared with model setup containing their simple-sum counterparts. Using both money supply and money demand, the role of ‘money’ has been evaluated in the structural vector autoregression setup for India, Poland and United Kingdom. The results of the study show that models with money especially Divisia money (i) help correctly identify shock to monetary policy (ii) shows more significant response of exchange rate to policy shock (obtained by Random Walk Metropolis Hastings method of Bayesian Monte Carlo integration) (iii) remove some of persistent puzzles like price puzzle, exchange rate puzzle and forward discount bias puzzle (iv) facilitate policy variables explain more of exchange rate fluctuations (v) generate better out-of-sample exchange rate forecast values in terms of RMSE and Theil U (obtained by estimating the model using Kalman filter) and (vi) generate better out-of-sample forecast graphs for exchange rates (obtained through Gibbs Sampling on a Bayesian VAR with a “Minnesota” prior)

Acknowledgments

Critics often point out that economists are in the profession of making common sense look rocket science! I am deeply grateful to my adviser, Professor William A. Barnett, who has been a rocket scientist by profession for bringing common sense in the field of economics. Professor Barnett has convinced me about the pressing need to use quality data in economic research and analysis. While it is true that the data generated from theoretically consistent approaches are potentially difficult to dig up. However this should remain the uncompromising path to improving our understanding of the economic phenomena. Also I will like to express my sincere appreciation to Professor Shu Wu, for his unstinted and continuous support during my doctoral program at K.U. I want to thank Professor John Keating for sharing his knowledge on time series econometrics with me and also for many such long, captivating conversation at his office. I want to thank Professor Prakash Shenoy for being always accessible and supportive. I will also like to thank Dr. Ryan Mattson for his practical advice and guidance during my graduate program. I want to specially thank Michelle Huslig-Lowrance who has gone out of her way to help me and made it possible for me to do my final defense.

This dissertation is gratefully dedicated to my

Mom and Dad,

Iera di and Promothesh da.

Table of Contents

Chapter 1: Exchange Rate Overshooting in Small Open Economies: A Reassessment in a Monetary Framework.....	1
1.1 Introduction	1
1.2 Dornbusch's exchange rate overshooting hypothesis.....	5
1.3 A theoretical framework to the short-run and long-run restrictions.....	6
1.4 Estimation.....	12
1.4.1 Model.....	12
1.4.2 Identification.....	15
1.5 Empirical Results.....	19
1.5.1 Impulse Response Functions.....	19
1.5.2 Variance Decomposition Analysis.....	28
1.5.3 Forecast statistics for Exchange Rate.....	34
1.6 Conclusion.....	38
Chapter 2: An SVAR Approach to Evaluation of Monetary Policy in India:Solution to the Exchange Rate Puzzles in an Open Economy	39
2.1 Introduction	39
2.2 The Indian Economy at a Glance	43
2.3 Estimation.....	45
2.3.1 Model.....	45
2.3.2 Identification.....	49
2.4 Empirical Results.....	52
2.4.1 Impulse Response Analysis.....	52

2.4.2 Variance Decomposition	61
2.4.3 Flip-flop Analysis.....	65
2.4.4 Forecast Statistics for Exchange rate.....	67
2.5 Conclusion.....	73
Chapter 3: Divisia Model of Exchange Rate Determination: A Multi-country Analysis	74
3.1 Introduction	75
3.2 Toda-Yamamoto Granger Causality.....	80
3.3 Estimation.....	90
3.3.1 Model.....	90
3.3.2 Identification.....	92
3.4 Empirical Results.....	95
3.4.1 Impulse Response Analysis.....	95
3.4.2 Variance Decomposition.....	103
3.4.3 Forecast Statistics for Exchange rate.....	107
3.5 Conclusion.....	113
References	115
Appendix	121

List of Figures

Figure 1: Impulse Responses to Monetary Policy Shock for Australia.....	21
Figure 2: Impulse Responses to Monetary Policy Shock for New Zealand.....	23
Figure 3: Impulse Responses to Monetary Policy Shock for Sweden.....	25
Figure 4: Impulse Responses to Monetary Policy Shock for Canada.....	27
Figure 5: Impulse Response to Money Demand Shock on Real Exchange Rate.....	33
Figure 6: Oil Price Index, World Commodity Price Index, CPI.....	44
Figure 7: Nominal and Real Interbank Rate for India.....	44
Figure 8: Interest Rate Differential, Exchange Rate for India.....	44
Figure 9: Inter-bank Rate, M1, M3 Money Supply for India.....	44
Figure 10: Inter-bank rate, Divisia M2, Divisia M3, Divisia L1.....	45
Figure 11: Production of Total Industry, Seasonally Adjusted Index.....	45
Figure 12: Impulse Response to Monetary Policy Shock for India, Recursive.....	57
Figure 13: Impulse Response to Monetary Policy Shock for India, Non-recursive.....	58
Figure 14: Monetary Policy explaining Fundamental variables for India.....	66
Figure 15: Fundamental variables explaining Monetary Policy for India.....	67
Figure 16: Out of Sample Forecast Graph for India (Model without Money and Divisia M3).....	71
Figure 17: Out of Sample Forecast Graph for India (Model with simple-sum M3 and Divisia M3).....	73
Figure 18: Impulse Responses to Monetary Policy Shock for India.....	98
Figure 19: Impulse Responses to Monetary Policy Shock for U.K.....	100
Figure 20: Impulse Responses to Monetary Policy Shock for Poland.....	102
Figure 21: Out of Sample Forecast Graph for India (Model with simple sum M1 and Divisia).....	111
Figure 22: Out of Sample Forecast Graph for U.K. (Model with simple sum M1 and Divisia).....	112

Figure 23: Out of Sample Forecast Graph for Poland (Model with simple sum M1 and Divisia M1)113

List of Tables

Table 1: Forecast Error Decomposition Contribution (MS Shocks and MD Shocks to Exchange Rate Variation).....	29
Table 2: Forecast Error Decomposition Contribution (MS Shocks to Exchange Rate Variation).....	29
Table 3: Forecast Statistics for Exchange Rate using simple BVAR (Australia).....	35
Table 4: Forecast Statistics for Exchange Rate using simple BVAR (Canada).....	35
Table 5: Forecast Statistics for Exchange Rate using simple BVAR (New Zealand).....	37
Table 6: Forecast Statistics for Exchange Rate using simple BVAR (Australia).....	37
Table 7: Recursive and Non-recursive Model Setups for India.....	54
Table 8: Model Analysis in terms of Puzzles.....	56
Table 9: Forecast Error Variance Decomposition Analysis for India.....	63
Table 10: Forecast Statistics for Exchange Rate (India).....	69
Table 11: Marginal Significance Level of the Monetary Indicators (Poland).....	85
Table 12: Marginal Significance Level of the Monetary Indicators (India).....	86
Table 13: Marginal Significance Level of the Monetary Indicators (U.K.).....	87
Table 14: Variance Decomposition of Exchange Rate due to Monetary Policy Shock.....	105
Table 15: Variance Decomposition of Exchange Rate due to Money Demand Shock.....	106
Table 16: Forecast Statistic Root Mean Square Error.....	108

Chapter 1: Exchange Rate Overshooting in Small Open Economies: A Reassessment in a Monetary Framework

1.1 Introduction

There has been a remarkable drop in the price of crude oil since mid-2014. The price of crude oil went below \$30 per barrel beginning in January, 2016. Overall in the last one and a half years, crude oil prices have dropped by more than 80%. Olivier Korber, derivatives strategist at Societe General, a France- based banking group, has done some interesting market analysis on currency and oil price movements. The analysis targets the world's major commodities currencies, including Canada. Mr. Korber predicts that at \$25 per barrel, the Canadian dollar would sink to just 70 cents USD. It would sink to 68.3 cents at \$20 a barrel and further down to 67.5 cents at \$17 a barrel. In fact, of all the leading commodity-based currencies in the world, the Australian dollar is down by more than 10%, New Zealand, which is reliant on the dairy export, has lost more than 15% of the currency value, and the Norwegian Krone is off nearly 5%. Barclay's commodity currency index, which measures the trade weights of the Canadian, Australian, New Zealand dollar and Norwegian Krone, was down more than 8% last year.

Such a sharp fall in commodity prices is beginning to have a deep-seated impact on resource reliant economies. In fact, Bank of Canada responded to the crisis by cutting interest rates for the second time in July last year in a span of 6 months. Stephen Poloz, Governor of the Bank of Canada, during a panel discussion at BIS meeting tried to explain the monetary policy stance. "The primary aim of the bank is achieving the inflation target. If the doctor however says you need surgery to avoid

death, you just go ahead and manage them somehow.”² In the aftermath of commodity price collapse, it will be interesting to try and understand why the Bank of Canada had to drastically implement such a rate cut measure. The analysis of the Canadian monetary policy is instructive not only because most countries resemble Canada in the sense that they are small and open relative to the U.S. economy, but also because it is of significant interest to U.S. policy makers as the U.S. economy has become increasingly integrated with the rest of the world.

We need to acknowledge that the oil sector makes more than 10% of the contribution to the Canadian GDP. No wonder Canadian residents’ income dropped significantly over the last one and a half year as the price of crude oil dropped. In fact the central bank of Canada lowered its growth outlook to 1.1% last year from a 1.9% forecast. The IMF has also cut its Canadian growth forecast from 2.2% to 1.5% last year. A fall in the Canadian income has decreased the demand for the Canadian currency which in turn lowered the exchange value of the Canadian ‘loonie’. In the short run, the general price level can have direct impact as the currency starts losing value (Dornbusch and Krugman, 1976). The recent rate cut measure by central banks might be an attempt to stabilize the exchange rate in order to achieve their inflation target.

Overall, tracking exchange rate movements seems a daunting task and beyond any measure of ‘fundamental,’ which is why it seems so difficult to explore and understand the same. Nevertheless in the aftermath of the commodity price collapse and weakening commodity currencies; rethinking on the central banks’ monetary policy and reassessing the response of the exchange rate turns out

² During a speech at the Bank for International Settlements (BIS) meeting, July, 2015. Dr. Stephen Poloz made it clear, he is not concerned about the consumer debt as he about Canada’s economic performance.

to be a relevant area of research. In the words of Kenneth Rogoff, “Even with the inevitable onslaught of the more modern approaches in economics, the Dornbusch model is still very much alive today. If one is in a pinch and needs a quick response to a question about how the monetary policy might affect the exchange rate, most of us will still want to check any answer against Dornbusch’s model.”-- IMF meeting (2001)

Surprisingly, studies of monetary policies have found exchange rate effects that are mostly inconsistent with Dornbusch overshooting. Eichenbaum and Evans (1995), Kim and Roubini (2000), Peersman and Smet (2003), Favero and Marcellino (2004), Mojon and Peersman (2003) and Linde (2003) have found results contrary to Dornbusch’s overshooting hypothesis. For example, Eichenbaum and Evans (1995) have worked with 5 different small, open economies, Japan, Germany, Italy, France and the U.K. Their result shows that contractionary monetary policy shock lead to sharp and persistent appreciation in both the real and nominal exchange rate. In the literature, this is referred to as the delayed overshooting or forward discount bias puzzle.

In fact, the majority of literature on small, open economies has tried to identify the monetary policy by using a recursive identification scheme. The researchers have either adopted an identification strategy that restricts the monetary policy from reacting contemporaneously to exchange rate movements (Sims, 1992; Eichenbaum and Evans, 1995) or they have restricted the exchange rate from reacting immediately to monetary policy shock (Favero and Marcellino, 2004; Mojon and Peersman, 2003). Bjornland (2009), however, finds evidence of exchange rate overshooting by acknowledging the simultaneity between monetary policy and the exchange rate for small, open economies. This identification restriction holds much relevance and seems crucial to capturing the exchange rate overshooting.

However, in the process of formulating a monetary policy, Cushman and Zha (1997) observe that the central bank must have a fairly accurate idea of the demand for Canadian currency. The important point that we cannot afford to miss here is central banks need to know: *How much of a change in the economy's money stock is influenced by monetary policy (i.e., money supply side) and how much of that change happens due to the monetary asset portfolio shifts of the private sector (i.e., money demand side)?* For example, if the money-demand increase in the economy and the central bank attempts to maintain a desired stock of money in order to keep inflation in check, we will need an economic model that explicitly separates the central bank's behavior from the private sectors' activity and thereby aid the policymakers' understanding of how much the money supply needs to be changed accordingly.

Similar argument has been put forward by Leeper and Roush (2003), who find that the liquidity effect and the impact of the rate cuts on output, inflation depend on how we capture the role of money in the model. Leeper and Roush compare between models without money and models with some contemporaneous interactions between money and funds rate, and find large and significant effects on the estimated real and nominal effects of policy.

Therefore attempts are made to reassess the Dornbusch's exchange rate overshooting hypothesis. As discussed before, it is difficult to identify the monetary policy and rightly capture the response of the exchange rate without knowledge of the money demand behavior of private agents. Therefore contrary to the work of Bjornland (2009), money is introduced back into the model along with the nominal short-term interest rate. Also correct error bands are computed, summing the lags of the coefficients drawn from Monte Carlo procedure, which is evidently not done by Bjornland. In order to make a direct comparison of my current work with Bjornland's original model, consideration is given to the same four countries Australia, Canada, New Zealand and Sweden, and using the dataset

identical to Bjornland. This model is able to get cases with significant impulse responses for all countries depicting exchange rate overshooting as predicted by Dornbusch.

If any model is used to perform innovation analysis, the interpretation of these innovations requires that identifying restrictions are imposed in order to isolate orthogonalized disturbance. Accordingly, a highly stylized two-country theoretical framework is introduced to illustrate the specific characteristics of monetary policy making in a small, open economy. Contemporaneous relations between endogenous variables and structural disturbances are added to the system, which can be inferred from the model. This helps specify a proper identification scheme that is used to perform the impulse-response analysis.

In subsection 1.2, we briefly discuss Dornbusch's exchange rate overshooting hypothesis, which is the central building block in international macroeconomics. Section 1.3 presents the two-country theoretical framework that helps illustrate the general characteristics of the monetary policy making in small, open economies. The model methodology, identification and empirical results are discussed in section 1.4 and 1.5. Finally, we conclude in section 1.6.

1.2 Dornbusch's exchange rate overshooting hypothesis

Rudiger Dornbusch's watershed paper, "Expectation and Exchange Rate Dynamics" was published in the Journal of Political Economy, in 1976. The paper elegantly explained the "overshooting" of the exchange rate. Dornbusch's exchange rate overshooting marks the birth of the modern international economics. So what exactly is the basic idea behind the Dornbusch's overshooting of the exchange rate? Two relationships lie at the heart of the overshooting result. Home interest rates on bond, must be equal to the foreign interest rate, plus the expected rate of depreciation, represented by equation (1.1). That is, if home and foreign bonds are perfect substitutes, and international capital mobility is fully mobile, the two bonds can pay different interest rates if agents

expect there will be compensating movement in the exchange rate.

$$i_{t+1} = i^* + E_t(e_{t+1} - e_t) \quad (1.1)$$

Also the higher interest rates raise the opportunity cost of holding money, and thereby lower the demand for money. Conversely, an increase in the output raises the transaction demand for money, shown in equation (1.2).

$$m_t - p_t = \eta i_{t+1} + \Phi y_t \quad (1.2)$$

Suppose there is a permanent decrease in the money supply. If nominal money supply drops but price level is temporarily fixed, then the supply of real balance must fall. To equilibrate the system, the demand for real balance must fall. Since output is assumed fixed in the short run, the only way the demand for real balance falls is if interest rate on domestic currency bonds rise. According to equation (1.1), it is possible for the interest rate on the domestic currency bond to rise, if and only if, over the future life of the bond contract, the home currency is expected to depreciate.

But how is it possible if we know the long run impact of the money supply reduction shock must be proportionate appreciation of the exchange rate? Dornbusch's brilliant answer: *the initial appreciation of the exchange rate must on impact, be larger than the long-run appreciation. This initial excess appreciation leaves room for the ensuing depreciation needed to simultaneously clear the bond and money market. Therefore the exchange rate must overshoot.*³

1.3 A theoretical framework to the short-run and long-run restrictions

³ "Expectations and Exchange Rate Dynamics" was published in the Journal of Political Economy in 1976.

In this section a theoretical framework is provided similar to Jan Kakes et al. (1998) and a highly stylized two-country model is presented to illustrate the general characteristics of monetary policy making in small, open economies (Australia, Canada, Sweden, New Zealand) anchored to a large, open U.S. economy. The theoretical framework helps in deriving short-run relation between endogenous variables. There are additional long run policy neutrality assumptions. Both the demand for real money balance and the real exchange rate are rendered long run neutral to monetary policy shock. The short run and long run restrictions are used together to specify an exact-identification scheme.

The model consists of the IS curve, a money market equation, a short-term interest rate function, an inflation equation and an equation for the expected inflation as the core set of equations for the domestic economy. Additionally, the trade weighted foreign interest rate and the real exchange rates are used in the *SVAR* analysis. All the variables except the central bank policy rates are written in logs.

Assumption: It is assumed that the perfect capital mobility holds, i.e., uncovered interest parity. In addition the central bank of a small, open economy tries to set the policy rate with the aim of influencing the level of economic activity and stabilize the exchange rate.

IS curve

The IS curve relates the aggregate demand y_t to the real capital market rate i.e. real long term interest rate, r_t^l . The aggregate demand y_t is seen to be affected by the real exchange rate, Ω_t . In addition, IS curve relates the aggregate demand to an IS shock, ε_t^y

$$y_t = -\alpha r_t^l + \beta \Omega_t + \varepsilon_t^y \quad (1.3)$$

Notice that the real long term interest rate is nominal (i_t^l) rate minus the expected inflation (π_t^e). i.e.

$$r_t^l = i_t^l - \pi_t^e \quad (1.4)$$

And the real exchange rate is the nominal exchange rate (η_t) adjusted of the domestic and foreign prices respectively.

$$\Omega_t = \eta_t - p_t + p_t^* \quad (1.5)$$

Jan Kakes modelling of the IS curve equation is represented by equation (1.3). However notice that the movements in the real exchange rates may not immediately influence the aggregate demand. This is believed to be a more realistic assumption given the existence of structural rigidities and time lags. For example, Kohler, Manalo, Perera (2014) (KMP) try to estimate the effect of the movements in the real exchange rate on the level of economic activity and inflation for Australia.

KMP's estimation results are based on the Lawson and Rees (2008) SVAR model and Jaaskela and Nirmak (2001) DSGE model. KMP find that a temporary change in exchange rate has the peak effect on the level of GDP, which is 0.3-0.6% in the SVAR and 0.4% in the DSGE model. More importantly the peak timing on the level of GDP (due to temporary changes in the exchange rate) is at least 4-6 quarters and 2 quarters in the SVAR and DSGE model respectively. If there is permanent change in the exchange rate, the peak timing on the level of GDP would be 7-9 quarters and 3 quarters in the SVAR and DSGE model respectively.

Therefore given the empirical evidence about the lagged response of the economic activity to an exchange rate movement, it will be sensible to modify the IS curve equation. The revised IS curve equation is the following.

$$y_t = -\alpha r_t^l + \varepsilon_t^y \quad (1.3)'$$

Money Market equation

The money market equation relates the real money demand, $(m_t - p_t)$ to the higher real economic activity, y_t . The real money demand, $(m_t - p_t)$ also depends on the nominal long-term

interest rate, i_t^l and a money market shock term, ε_t^m . In addition, notice that the short-term interest rate, i_t^s , is likely to have a positive impact on the money demand (Fase and Winders, 1996).

$$m_t - p_t = \gamma y_t - \zeta i_t^l + \delta i_t^s + \varepsilon_t^m \quad (1.6)$$

In a small, open economy with perfect capital mobility, money is demand determined. In addition, the small, open economy long term interest rate are implicitly assumed to be equal to the U.S. counterparts.

Monetary Policy

The general form of the interest rate rule by Devereux (1999) may be written as:

$$(d_{t+1}^h)^{-1} = \left(\frac{P_{Nt}}{P_{Nt-1}} \frac{1}{1 + \pi_n} \right)^{\mu_{\pi n}} \left(\frac{P_t}{P_{t-1}} \frac{1}{1 + \pi} \right)^{\mu_{\pi}} \left(\frac{Y_t}{Y} \right)^{\mu_Y} \left(\frac{S_t}{S} \right)^{\mu_S} (1 + i') \exp(u_t)$$

$$\mu_{\pi n} \geq 0, \mu_{\pi} \geq 0, \mu_Y \geq 0, \mu_S \geq 0$$

The parameter $\mu_{\pi n}$ allows the monetary authority to control the inflation rate in the non-traded goods sector around the target rate of π_n . The parameter μ_{π} governs the degree to which the CPI inflation rate is targeted around the desired target of π . Then μ_Y and μ_S control the degree to which the interest rates attempt to control variations in aggregate output and the exchange rate, around the target levels of Y and S respectively. The term $\exp(u_t)$ represents a shock to the domestic monetary rule.

The function allows for a variety of the monetary rules. When $\mu_{\pi n} \rightarrow \infty, \mu_{\pi} = \mu_Y = \mu_S = 0$, the monetary authorities pursue a policy of strict inflation targeting in the non-traded goods sector. When $\mu_{\pi n} = \mu_S = 0$, the authority follows a form of Taylor rule, where the interest rates are adjusted to respond to the deviations of the CPI inflations and aggregate output for some target levels.

When $\mu_{\pi n} = 0$, the authority follows a modified Taylor rule, in which the exchange rate is targeted in addition to CPI inflation and output. When $\mu_{\pi} \rightarrow \infty, \mu_{\pi n} = \mu_Y = \mu_S = 0$, the monetary authorities pursue strict inflation targeting. Finally, when $\mu_S \rightarrow \infty, \mu_{\pi n} = \mu_Y = \mu_{\pi} = 0$, the authority follows a pegged exchange rate.

In the economy with the slow pass-through of the exchange rate changes, the situation is more complicated, because even without sticky prices in the non-traded goods sector, monetary rules can have real effects through their impact on the exchange rate. This may lead the monetary authority to be more generally concerned with CPI inflations and nominal exchange rate variability, as pointed out by Devereux (1999). “The pass-through of exchange rates to inflation was much higher in Mexico than in Canada, Australia or New Zealand. And this has to do a lot with history, with credibility of monetary policies”⁴—Guillermo Ortiz, Governor, Central Bank of Mexico. So I believe that industrial economies with slow exchange rate pass-through like Australia, Canada, Sweden, New Zealand) might have the Taylor rule, in which the exchange rate is targeted in addition to CPI inflation and output.

The central bank of a small, open economy sets the short-term interest rate primarily to stabilize the exchange rate. For example, a rise in the rate of interest in Australia relative to overseas (U.S.) would give investors a higher return on the Australian assets relative to their foreign currency equivalents. This will make the Australian assets more attractive with inflow of capital affecting the exchange

⁴ The pass-through of exchange rates to inflation was much higher in Mexico than in Canada, Australia or New Zealand. And this has to do a lot with history, with credibility of monetary policies, and this is one of the big challenges that we are facing today in Mexico in the conduct of monetary policy. We have to build sufficient credibility so that the pass-through from exchange rate movements to inflation ceases to be such an automatic reaction—Guillermo Ortiz, Governor, Central Bank of Mexico, 24th June, 1999.

rate. Also the bank's monetary policy objective is to deliver price stability (inflation target) coupled with the government's economic objectives of growth and employment. Therefore the central bank's policy rule for a small, open economy is the following.

$$i_t = i_t^* + \Phi_1(y_t - y_t^n) + \Phi_2(\pi_t - \pi_t^*) + \varepsilon_t^i \quad (1.7)$$

Expected domestic inflation

The Federal Reserve aims at keeping inflation at a 'core' level, π_t^* . The small open economy imports the low U.S. inflation level. Therefore, expected domestic inflation equals U.S. 'core' plus a Gaussian error term.

$$\pi_t^e = \pi_t^* + v_t \quad (1.8)$$

The actual inflation in U.S. is determined by the

$$\pi_t^* = p_t^* - p_{t-1}^* = \pi_t^* + v_t^* \quad (1.9)$$

Domestic Inflation

The inflation in the small, open economy is equal to the expected inflation plus a shock term

$$\pi_t = p_t - p_{t-1} = \pi_t^e + \varepsilon_t^\pi = \pi_t^* + v_t + \varepsilon_t^\pi \quad (1.10)$$

To solve the model, the expectation formation process equation (1.8), equation (1.4) and actual inflation equation (1.10) is inserted in the modified IS curve equation (1.3)'

$$y_t = y^c - \alpha i_t^* - \alpha \varepsilon_t^\pi + \varepsilon_t^y; \text{ where } y^c = \alpha \pi_t^* + \alpha v_t^{\pi*} \quad (1.11)$$

Plugging the value of y_t from (1.11) in the monetary policy equation (1.7),

$$i_t = i^c - \Phi_1 \alpha \varepsilon_t^\pi + \Phi_1 \varepsilon_t^y + \varepsilon_t^i \quad (1.12)$$

where $i^c = i_t^* + \Phi_1 y^c - \Phi_1 \alpha i_t^{l*} - \Phi_1 y_t^n + \Phi_2 v_t^{\pi*}$

Plugging the value of equation (1.11), equation (1.12) in the money market equation (1.6)

$$\mathbf{m}_t - \mathbf{p}_t = \mathbf{m}^c - [\gamma\alpha + \delta\Phi_1\alpha]\varepsilon_t^\pi + [\delta\Phi_1 + \gamma]\varepsilon_t^y + \delta\varepsilon_t^i + \varepsilon_t^m \quad (1.13)$$

where $\mathbf{m}^c = [\gamma y^c - \gamma\alpha i_t^{l*} - \zeta i_t^{l*} + \delta i^c]$

Equation (1.10), (1.11), (1.12), (1.13), shows the core set of variables, represented in terms of the structural shocks in the matrix form. We will use the derived relationships between the core-variables in designing our identification restriction in the next section.

$$\begin{pmatrix} \pi_t \\ gdp_t \\ rdom_t \\ M/P_t \end{pmatrix} = \begin{pmatrix} b_{11} & 0 & 0 & 0 \\ b_{21} & b_{22} & 0 & 0 \\ b_{31} & b_{32} & b_{33} & 0 \\ b_{41} & b_{42} & b_{43} & b_{44} \end{pmatrix} \begin{pmatrix} \varepsilon_t^\pi \\ \varepsilon_t^{gdp} \\ \varepsilon_t^{rdom} \\ \varepsilon_t^{M/P} \end{pmatrix} \quad (1.14)$$

1.4 Estimation

1.4.1 Model

The model comprises of a 6-variables $VAR, Y_t = [rfor, \pi, gdp, rdom, \Delta M/P, \Delta RER]'$ with $rfor$ = trade weighted foreign interest rate, π = the level of inflation in the domestic small open economy, gdp = real output, $\Delta M/P$ = first difference of real money where the monetary aggregate $M1$ ($M3$ for Sweden) is deflated by consumer prices representing money demand shocks (ΔMD), (ΔRER) = first difference of real exchange rate is the domestic currency per trade weighted foreign currency and $rdom$ = nominal short-term domestic interest rate producing monetary policy shocks (MP).

The reduced form $VAR(p)$ can be written as:

$$Y_t = A_1 Y_{t-1} + \dots + A_p Y_{t-p} + u_t \quad (1.15)$$

$$\text{or, } Y_t - A_1 Y_{t-1} - \dots - A_p Y_{t-p} = u_t$$

$$\text{or, } Y_t - A_1 L Y_t - \dots - A_p L^p Y_t = u_t$$

$$or, (1 - A_1L - \dots - A_pL^p)Y_t = u_t$$

$$or, A(L)Y_t = u_t \quad (1.16)$$

The VAR is assumed to be stable, invertible and can be alternatively written in terms of its moving average representation, $Y_t = C(L)u_t$; u_t is the vector of reduced form residual and can be written as $u_t = Y_t - Proj(Y_t|Y_{t-1}, \dots, Y_{t-p})$, where, $E(u_t u_t') = \Sigma_u$. The $C(L)$ is the convergent matrix polynomial in the lag operator L . $C(L) = C_0 + C_1L^1 + C_2L^2 + \dots = \sum_{j=0}^{\infty} C_jL^j$. The underlying orthogonal structural disturbance ϵ_t is assumed to be written as the linear combination of the reduced form residual u_t , $u_t = R\epsilon_t$. The VAR can be written in terms of the structural shock as follows;

$$Y_t = D(L)\epsilon_t \quad (1.17)$$

where, $D(L) = C(L)R$ and $u_t = R\epsilon_t$. To go from the reduced form VAR to structural interpretation, restrictions need to be imposed on R . If we can identify R , one can derive the MA representation. Notice that $C(L)$ can be calculated from the reduced form estimation. In order to move from the reduced form VAR to structural interpretation, restrictions need to be applied on R . It is possible to recover the structural parameters from the covariance matrix of the reduced form residual. The structural shock, $\epsilon_t = [\epsilon_t^{rfor}, \epsilon_t^\pi, \epsilon_t^{gdp}, \epsilon_t^{MP}, \epsilon_t^{\Delta MD}, \epsilon_t^{\Delta RER}]'$ is the vector of uncorrelated structural shock. An expression for ϵ_t can be written as $E(\epsilon_t \epsilon_t') = \Sigma_\epsilon$. The VAR in terms of the structural shock can be represented in terms of the matrix notation;

$$\begin{pmatrix} rfor \\ \pi \\ gdp \\ MP \\ \Delta MD \\ \Delta RER \end{pmatrix} = C(L) \begin{pmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} & r_{16} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} & r_{26} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} & r_{36} \\ r_{41} & r_{42} & r_{43} & r_{44} & r_{45} & r_{46} \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} & r_{56} \\ r_{61} & r_{62} & r_{63} & r_{64} & r_{65} & r_{66} \end{pmatrix} \begin{pmatrix} \epsilon_t^{rfor} \\ \epsilon_t^\pi \\ \epsilon_t^{gdp} \\ \epsilon_t^{MP} \\ \epsilon_t^{\Delta MD} \\ \epsilon_t^{\Delta RER} \end{pmatrix} \quad (1.18)$$

So an exactly identified system is employed with both the short run and the long run restriction. The real exchange rate and the real money balance are differenced so that when long-run restrictions are applied to the first differenced real exchange rate and first differenced real money balance, the effects of a monetary policy shock on the level of the real exchange rate and real money balance will sum to zero. This is based on the assumption of the long-run monetary policy neutrality.

To elaborate more on the long run restriction, decomposition similar to the Blanchard and Quah technique is applied. Consider two shocks: $\Delta M/P$ (ΔMD) and $rdom$ (MP). The long-run restriction used for identification is that money supply shock has no long run effects on the demand for real money balance. Consider the following bivariate VAR;

$$\begin{pmatrix} MP \\ \Delta MD \end{pmatrix} = \begin{pmatrix} D(L)_{11} & D(L)_{12} \\ D(L)_{21} & D(L)_{22} \end{pmatrix} \begin{pmatrix} \epsilon_t^S \\ \epsilon_t^D \end{pmatrix} \quad (1.19)$$

Where $rdom$ is the domestic rate of interest, M/P is demand for real balance of money and $\epsilon_t^S, \epsilon_t^D$ are the monetary policy and the money demand disturbance respectively. The long-run identification restriction is given $D(L)_{21} = 0$. The restriction can be implemented in the following way. Let us consider the reduced form VAR

$$\begin{pmatrix} MP \\ \Delta MD \end{pmatrix} = \begin{pmatrix} C(L)_{11} & C(L)_{12} \\ C(L)_{21} & C(L)_{22} \end{pmatrix} \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix} \quad (1.20)$$

where, $E(u_t u_t') = \Sigma_u$ and $S = chol(C(1)\Sigma_u C(1)')$ with $R = C(1)^{-1}S$. The identified shocks are given by $\epsilon_t = R^{-1}u_t$. The resulting impulse response to the structural shocks are $D(L) = C(L)R$ and notice that the restrictions are satisfied at $L=I$, we have $D(1) = C(1)R = C(1)C(1)^{-1}S = S$, which is the upper triangular implying $D(L)_{21} = 0$. We can do a similar bivariate VAR analysis with the domestic rate of interest and the real exchange rate where the monetary policy shocks have transitory effects on the real exchange rate but has no long run effect.

1.4.2 Identification

This is a 6-variable VAR⁵ that includes trade weighted foreign interest rate ($rfor$), the level of inflation in the domestic small open economy (π), real output (gdp), first difference of real money balance where real money balance is the M1 (or M3) monetary aggregate deflated by the consumer prices (ΔMD), first difference of real exchange rate, domestic currency per trade weighted foreign currency (ΔRER) and nominal short-term domestic interest rate (MP). The short-run identification scheme is based on equation (1.21) given below.

$$Y_t = \begin{pmatrix} rfor_t \\ \pi_t \\ gdp_t \\ MP_t \\ \Delta MD_t \\ \Delta RER_t \end{pmatrix} = C(L) \begin{pmatrix} r_{11} & 0 & 0 & 0 & 0 & 0 \\ r_{21} & r_{22} & 0 & 0 & 0 & 0 \\ r_{31} & r_{32} & r_{33} & 0 & 0 & 0 \\ r_{41} & r_{42} & r_{43} & r_{44} & 0 & b_{46} \\ r_{51} & r_{52} & r_{53} & r_{54} & r_{55} & b_{56} \\ r_{61} & r_{62} & r_{54} & r_{64} & r_{65} & b_{66} \end{pmatrix} \begin{pmatrix} \epsilon_t^{rfor} \\ \epsilon_t^\pi \\ \epsilon_t^{gdp} \\ \epsilon_t^{MP} \\ \epsilon_t^{\Delta MD} \\ \epsilon_t^{\Delta RER} \end{pmatrix} \quad (1.21)$$

ϵ is the vector of structural innovations, the vector Y_t represents the following variables: foreign interest rate, inflation, real output, money demand, monetary policy, and real exchange rate. The restrictions on R_0 are motivated from the relationship derived between the core-variables from the theoretical framework. Foreign interest rate in a small open economy set-up appears exogenous with none of the domestic variables being able to affect it contemporaneously (but can do so over time).

⁵ It is shown that differencing of variables does not provide gain in asymptotic efficiency of the model and may throw away information regarding co-movements in the data like cointegrating relationship between the variables in a VAR.

This paper tries to study the effect of an exogenous monetary policy shock on macroeconomic variables in a domestic economy. It is necessary to include the foreign interest rate to isolate and control the exogenous component of monetary policy shocks. An additional behavioral restriction often imposed is that certain variables respond slowly to movements in financial and policy variables due to nominal rigidities. So, for example, output and prices respond to changes in domestic monetary policy variables and exchange rates with a lag, but output and prices do respond to the foreign interest rate contemporaneously. Also output responds to domestic price instantaneously.

The standard money demand function usually depends on output, prices and the domestic interest rate. People's willingness to hold cash in an open economy could also depend on foreign interest rates and exchange rates. Monetary policy equation is assumed to be the reaction function of the monetary authority, which sets the interest rate after observing the current level of economic activity and exchange rate movements. Also when the monetary authority sets its interest rate, we assume that it keeps an eye on the foreign interest rate, which may have serious consequences on a small open economy. The real exchange rate variable in the model is the most volatile variable and is quick to react to both external and domestic shocks.

The ordering of first three variables are foreign interest rates, inflation and output. The domestic short-term nominal interest rate is the monetary policy instrument. For small open economies, the exchange rate is quick to react to movements in other variables. Therefore exchange rate is placed at the end in the ordering of the variables. Bjornland (2009) points out in order to achieve identification most VAR models impose one-way restrictions on contemporaneous interactions between monetary policy and real exchange rates (using recursive identification strategy).

In fact, failing to correctly capture the interaction between the variables has led to various empirical

puzzles and results inconsistent with Dornbusch's theory. Bjornland tries to tackle the problem by acknowledging the two-way interaction between monetary policy and real exchange rate in the short-run. Bjornland keeps the short-run (that is the contemporaneous) relation between monetary policy and the real exchange rate free, but instead imposes an additional restriction of long-run money neutrality. By doing so, she is able to capture the overshooting of the exchange rate. But the results hold 'insignificant' in some cases as shown by the impulse responses in the next section.

The identification of monetary policy in a model without knowing the money demand behavior of a private agent is neither reasonable nor fundamentally appealing. In an effort to improve the model, a money demand equation is added to the model and a 6-variable VAR system is employed. The advantage of the model is we keep the short-run interactions between the three variables- money, domestic interest rates and the real exchange rate-as free as possible. The free interaction in the short-run between monetary policy and exchange rates is a crucial assumption in order to capture accurately the exchange rate dynamics, as we believe there is a two-way interaction between the variables (that is, real exchange rate affects monetary policy and monetary policy in turn, affect real exchange rates) in the short-run.

An additional short-run restriction of $r_{45} = 0$ in (1.21) is used to identify the money supply vis-à-vis money demand. $r_{45} = 0$ is set at zero in the short run (follows from the theoretical framework in section 1.2). There is a two way interaction between real money demand and real exchange rates. In order to achieve exact identification, we assume long-run policy neutrality according to which the monetary policy shock does not affect the real money demand and the real exchange rate in the long run. This assumption allows us to estimate the structural model with fewer restrictions on instantaneous relationships between the financial and policy variables and identify monetary policy.

The long-run neutrality assumption where the monetary policy does not affect the real exchange rate as well as the real money demand in the long run is implemented by setting $D_{54}(1) = D_{64}(1) = 0$, where each element of $D(1)$ matrix is the sum of structural VAR coefficients.

$$D(1) = \begin{pmatrix} \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & 0 & \cdot & \cdot \\ \cdot & \cdot & \cdot & 0 & \cdot & \cdot \end{pmatrix} \quad (1.22)$$

The *SVAR* consists of real money demand and the real exchange rate in differenced form (ΔMD and ΔRER , respectively). The long-run restrictions on these two macroeconomic variables due to a monetary policy is imposed using restrictions on the long-run multiplier matrix which is the sum of coefficients in $D(1)$. Alternatively, the restriction that the monetary policy shock has no long-run effect neither on the real money balance nor on the real exchange rate is implemented by setting the values of the infinite number of the relevant lag coefficient, $\sum_{j=0}^{\infty} D_{54,j} = \sum_{j=0}^{\infty} D_{64,j} = 0$. This can be reiterated in the form of the long-run expression,

$$C(1)_{51}r_{14} + C(1)_{52}r_{24} + C(1)_{53}r_{34} + C(1)_{54}r_{44} + C(1)_{55}r_{54} + C(1)_{56}r_{64} = 0 \quad (1.23)$$

$$C(1)_{61}r_{14} + C(1)_{62}r_{24} + C(1)_{63}r_{34} + C(1)_{64}r_{44} + C(1)_{65}r_{54} + C(1)_{66}r_{64} = 0 \quad (1.24)$$

where the above long-run expression follows from, $C(L)R = D(L)$. Setting $L = 1$, we have $C(1)R = D(1)$. Also notice that $C(1)$ and $D(1)$ are the infinite series with the following expression, $C(1) = C_0 + C_1 + \dots = \sum_{j=0}^{\infty} C_j$ and $D(1) = D_0 + D_1 + \dots = \sum_{j=0}^{\infty} D_j$. The imposition of the long-run neutrality assumption makes the 6 variable VAR model to be exactly identified with $n(n-1)/2 = 15$ restrictions.

1.5 Empirical Results

The same dataset as Bjornland paper is used and it is directly taken from author's website to render comparison with this paper. The author's choice of the sample period is based on stable macroeconomic conditions in the respective countries. All the series are from OECD database except the Federal Funds rate which is from Ecwin. The authors use real effective exchange rate measured against a basket of trading partners and trade weighted foreign interest rates obtained from various sources (see Bjornland for details). Money, output and inflation are seasonally adjusted by the official sources. M1 money is used for all the analyses except for Sweden for which M3 money is used due to unavailability of early M1 data. All variables are in logarithms except the interest rates. Inflation (π) is calculated as the annual change in log of consumer prices. The quarterly VAR is estimated using 3 lags. The lags are selected by sequential likelihood ratio test in RATS (see Doan 2013). The results from sequential likelihood ratio test is presented in the appendix. Based on the results 3 lags are selected for all the countries except Canada for which 2 lags are selected. Bjornland uses 3 lags for all the countries in her model without money demand. Also our model is stable for all the countries given by the largest root being less than one (please see appendix).

1.5.1 Impulse Response Functions

Bjornland (2009) analyzes the Dornbusch exchange rate overshooting hypothesis. Although the author has tried to establish the hypothesis by showing on impact appreciation of exchange rates after a monetary policy shock and depreciation thereafter, we are not able to replicate the results. When we use corrected error bands, which are usually wider than reported by Bjornland, we get 'insignificant' impulse responses for exchange rate due to a monetary policy shock. The corrected error bands are computed using the lag sums for the coefficients drawn from the Monte Carlo

procedure rather than the OLS estimates of the coefficients. According to Tom Doan, “Error bands become wider when bands are generated using the lag sums from OLS estimate”⁶. The left panel in figures 1-4 display the impulse responses from a monetary policy shock in Bjornland’s original model for Australia, New Zealand, Sweden and Canada. The impulse response functions for exchange rate are insignificant in all four graphs. On the other hand, the right panel in figures 1-4 displays the impulse responses for our model for the four small open economies. We discuss the results in details below. In the graphs below the effect of monetary policy shock is normalized so that interest rates increase by one percentage point in the first month and a decrease in exchange rate implies appreciation. The statistical significance of impulse responses are examined using the Bayesian Monte Carlo integration in RATS to draw 1000 replications for the just-identified *SVAR* model. The 0.16 and 0.84 fractiles correspond to the upper and lower dashed lines of the probability bands (see Doan, 2013).

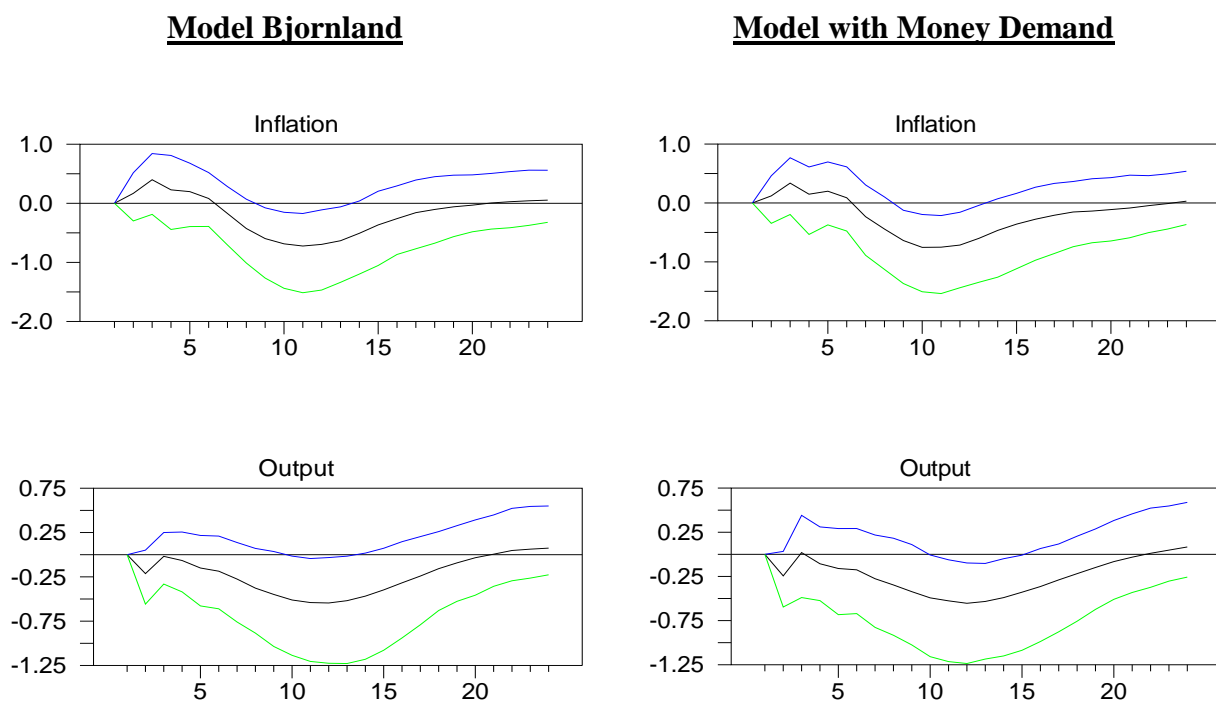
Figure 1 represents Australia’s impulse responses from a unit monetary policy shock for the period 1987 Q1 to 2004 Q4. The original Bjornland model for Australia exhibits ‘insignificant’ exchange rate overshooting for almost all sub-samples in the dataset as also seen in the graph (left panel). On the other hand, we see that the model with money demand (right panel), the intensity of exchange rate overshooting is more pronounced (significant) as compared to Bjornland’s original model. Similarly, the fall in prices and output due to a monetary shock is more pronounced in the model

⁶ In a forum for RATS Software and Econometrics Discussion, Tom Doan commented, “If the error bands are computed using the lag sums from the OLS estimates rather than the recomputed lag sums from the drawn coefficients (where the latter, reflected in what you did is the correct procedure). That almost certainly makes the error bands wider than they would be done correctly.

with money demand as seen in the second panel. On impact to a unit monetary policy shock real exchange rate appreciates by 5 percentage points before depreciating back to the long run equilibrium, output gradually falls by almost 0.5 percentage points and the fall is significant from 9-15 quarters, after a very small insignificant increase. Prices actually start falling significantly from 8-14 quarters and fall by almost 0.8 percentage points due to a unit monetary policy shock. Monetary aggregate falls by 3 percentage points and significantly from 4-8 quarters.

Figure 1: Impulse responses to Monetary Policy shock

Australia (1987:1-2004:4)



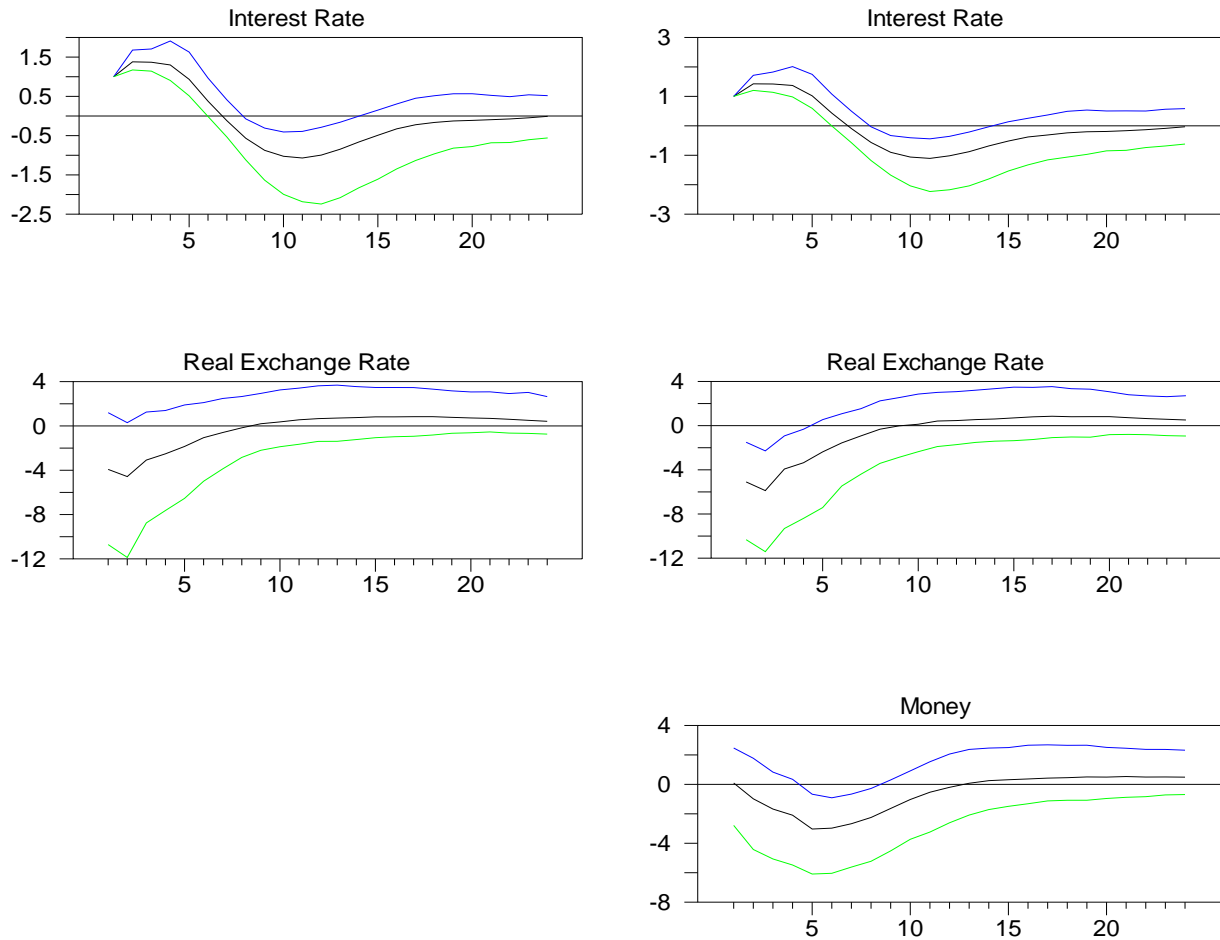
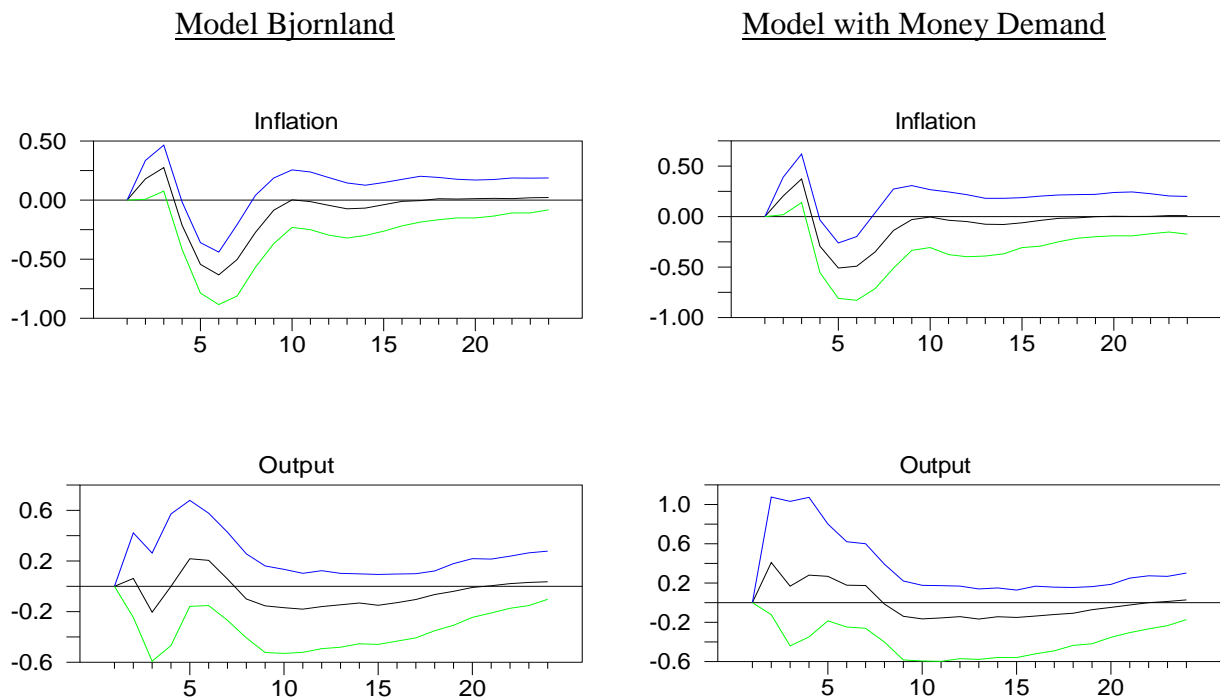


Figure 2 represents New Zealand's impulse responses from a unit monetary policy shock for the period 1990:1 Q1 to 2004 Q4. The original Bjornland model for New Zealand exhibit 'insignificant' exchange rate overshooting for almost all sub-samples in the dataset whereas our model (right panel) exhibit significant overshooting in more sub-samples than Bjornland (although not for all of them) . The exchange rate does appreciate on impact to a monetary policy shock in the original Bjornland model (left panel), but it is actually significant after a couple of quarters. However, the response of output in both the model remains insignificant throughout the sample due to a monetary policy shock. The response of money demand is also insignificant. More specifically, on impact to a unit monetary policy shock in our model real exchange rate appreciates

by 3 percentage points before depreciating back to the long run equilibrium. Prices fall significantly from 4-7 quarters and it falls by almost 0.5 percentage points due to a unit monetary policy shock.

Figure 2: Impulse responses to Monetary Policy shocks

New Zealand (1990:1-2004:4)



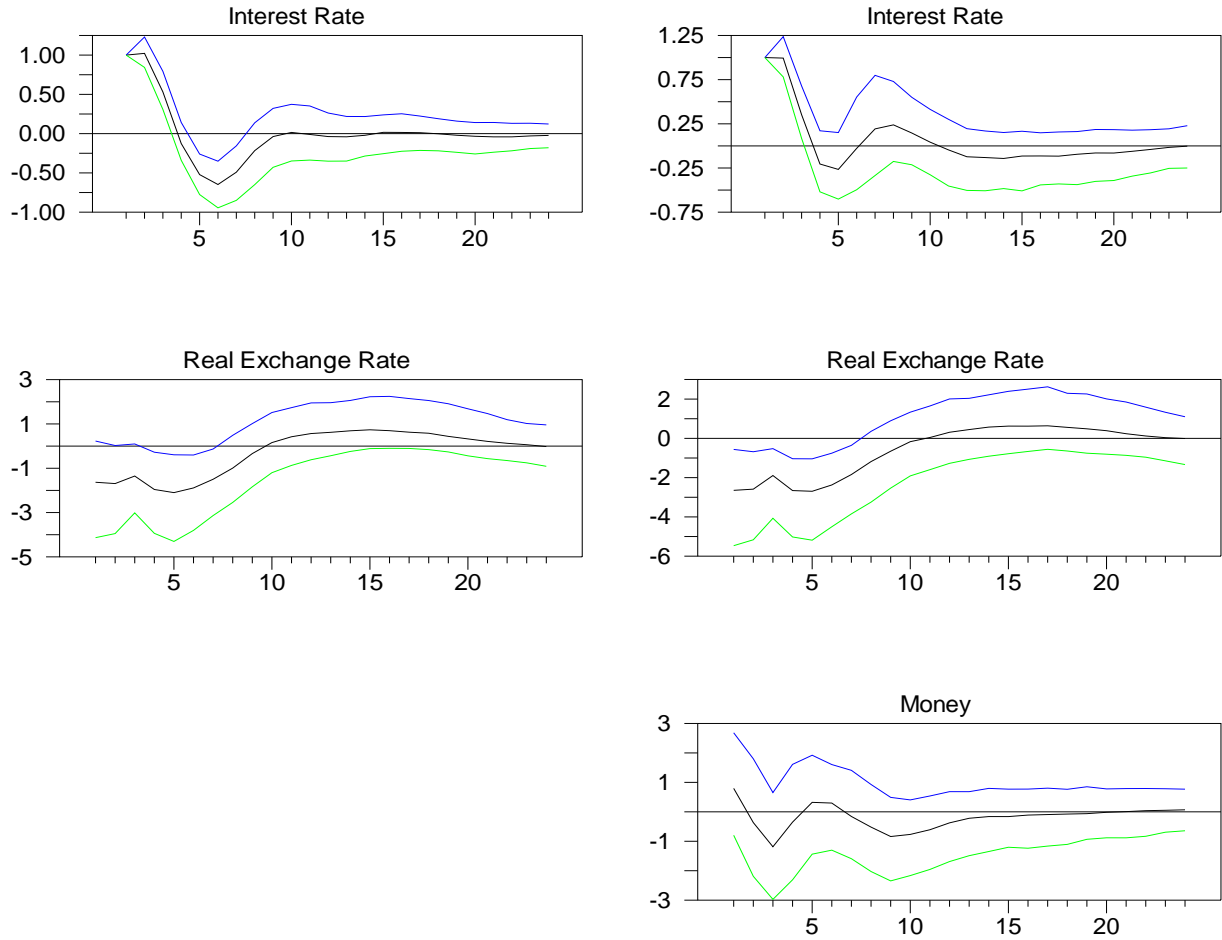


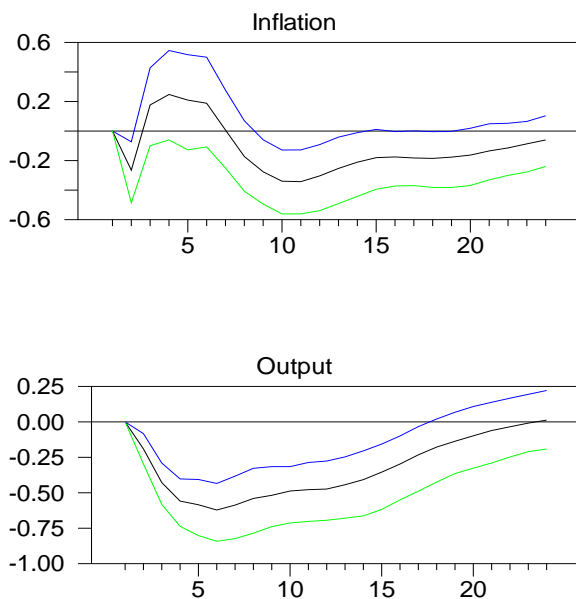
Figure 3 represents Sweden's impulse responses from a unit monetary policy shock for the period 1988 Q1 to 2003 Q4. The original Bjornland model for Sweden exhibits almost 'insignificant' exchange rate overshooting for many sub-samples in the dataset (left panel). On the other hand, our model as well (right panel) shows not quite significant exchange rate overshooting to a monetary policy shock. We suspect the unavailability of narrow monetary aggregate like M1 (only for Sweden) might be the reason for such response. The responses of prices and output are similar in both models. Prices, output and money demand all fall on impact to a monetary policy shock. On impact to a unit monetary policy shock in our model real exchange rate appreciates by 1.5 percentage points before depreciating back. Output

gradually falls by almost 0.7 percentage points and the fall is significant throughout. Prices fall by almost 0.4 percentage points and money significantly drops by 3 percentage points for the first four quarters.

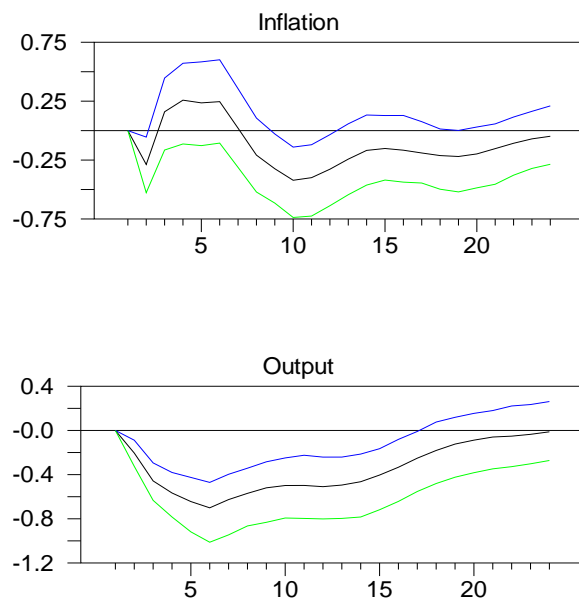
Figure 3: Impulse responses to Monetary Policy shock

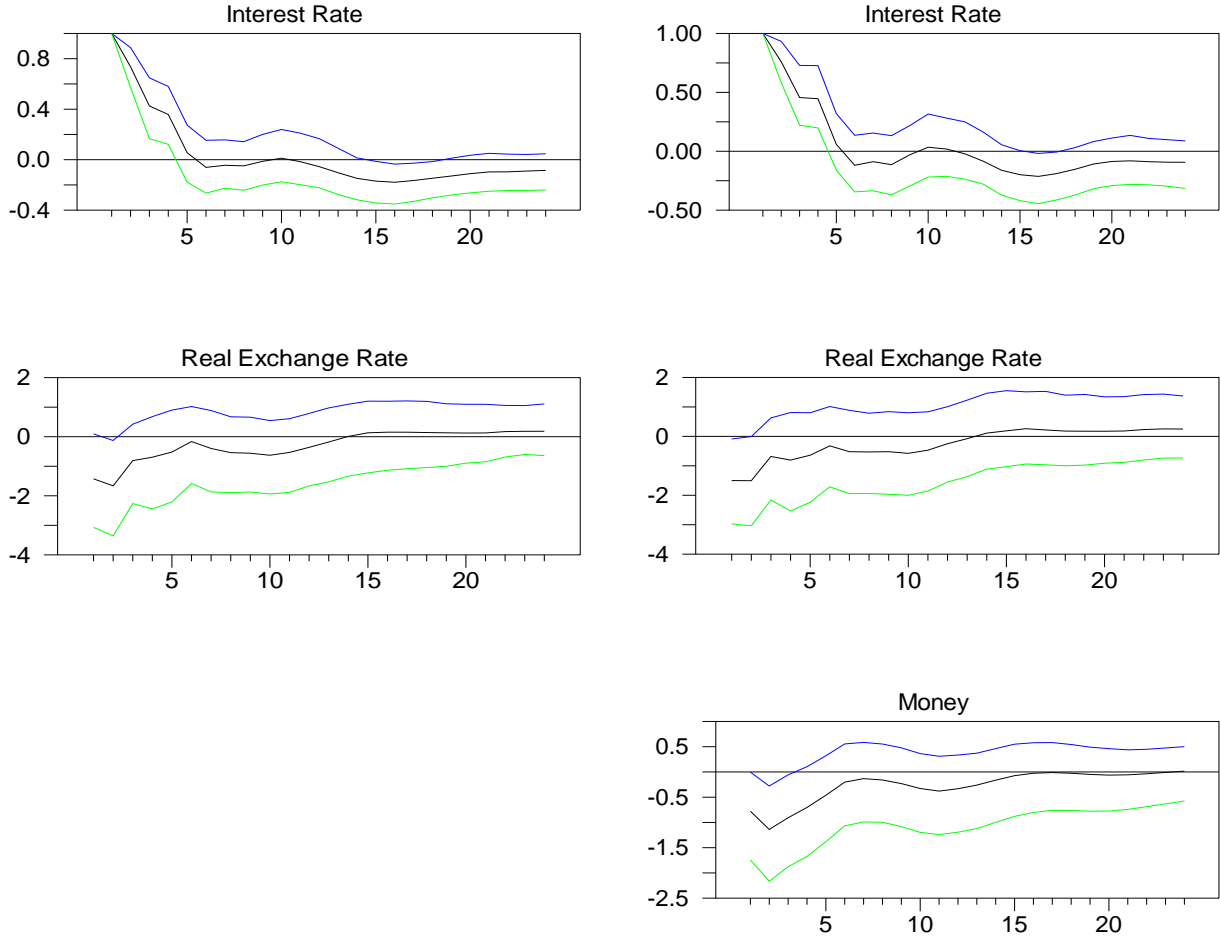
Sweden (1988:1 2003:4)

Model Bjornland



Model with Money Demand





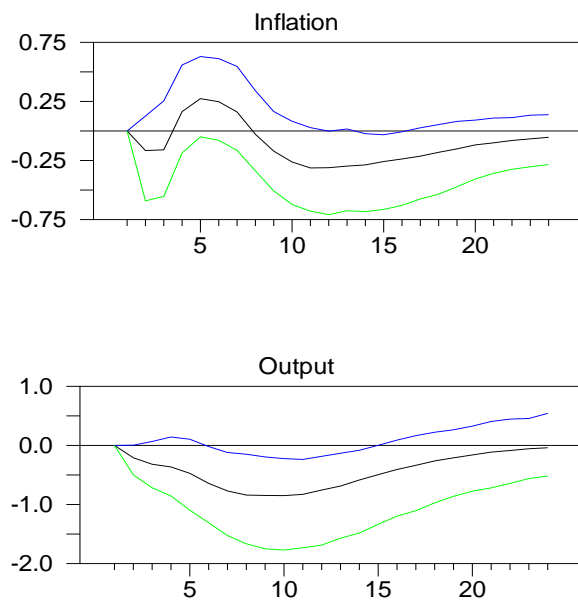
Similarly for Canada (figure 4) we can find subsamples where we get significant exchange rate overshooting for models where demand and supply aspect of money market is captured as opposed to models with interest rate being the only policy variable. Figure 4 gives impulse responses from a unit monetary policy shock for the period 1987 Q4 to 2004 Q4. Comparing the left and the right panel, we see that the original Bjornland model for Canada exhibit ‘insignificant’ exchange rate overshooting and the model with money demand produce significant exchange rate overshooting. We get the expected behavior of prices and output in the model due to a monetary shock. On impact to a unit monetary policy shock in our model real exchange rate appreciates by 3.75 percentage points before depreciating back to the long run equilibrium, output gradually falls by

almost 1.0 percentage points and the fall is significant after 5th quarter and prices fall by 0.375 percentage points significantly after 10th quarter due to a unit monetary policy shock. Money demand falls by almost 2 percentage points and significantly from 3-8 quarters.

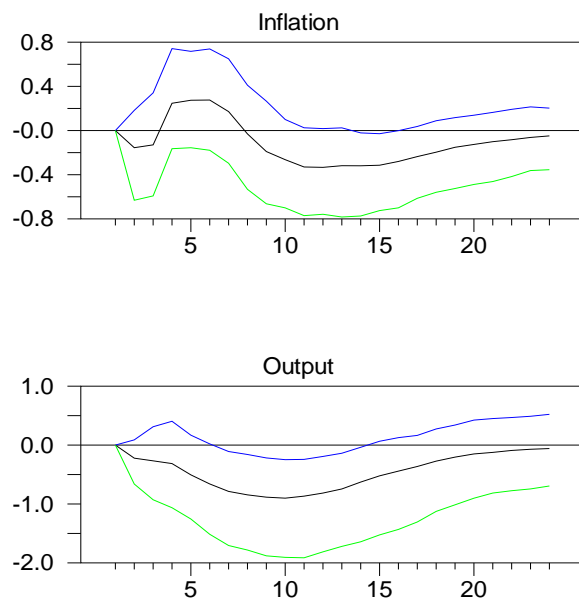
Figure 4: Impulse responses to Monetary Policy shock

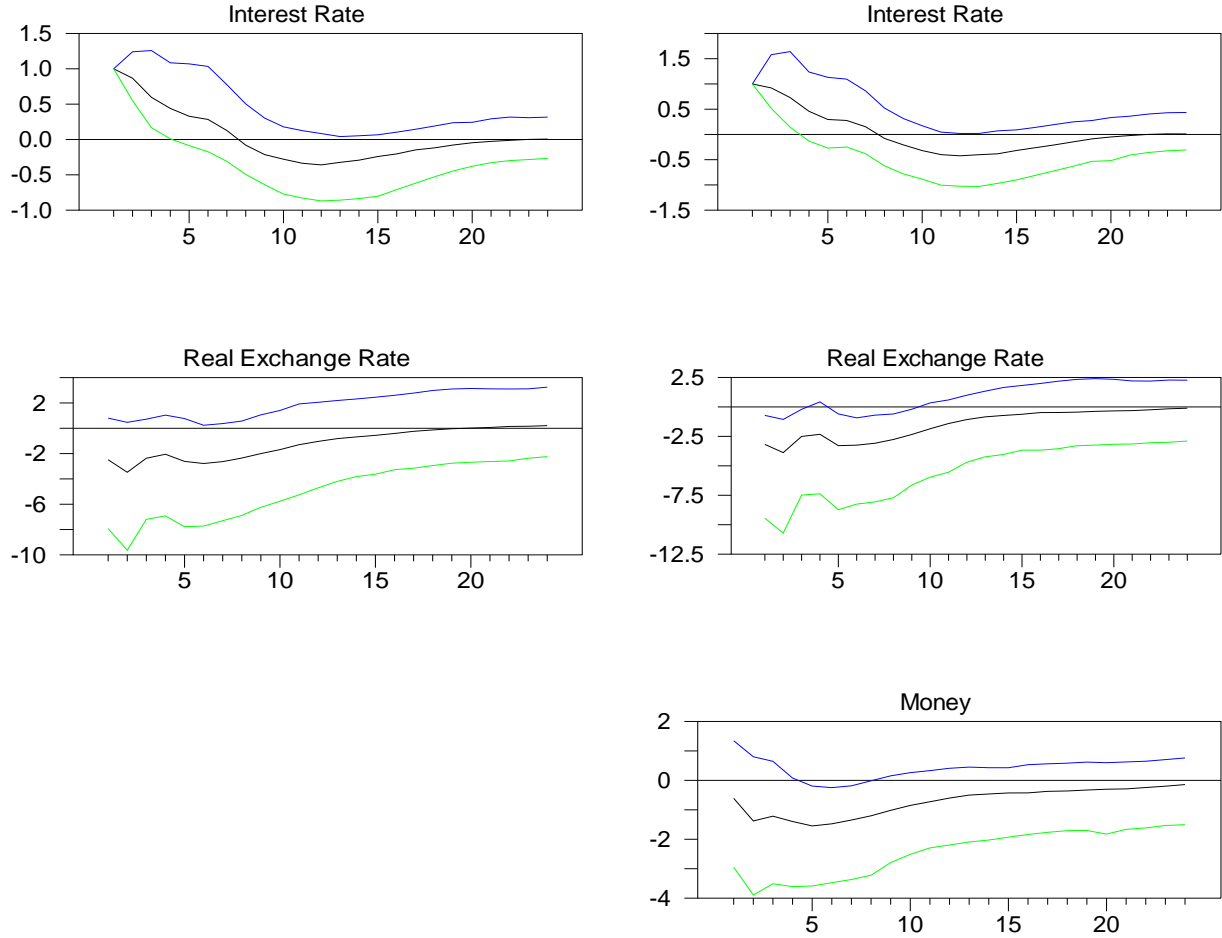
Canada (1987:4-2004:4)

Model Bjornland



Model with Money Demand





Robustness Check: The results for our model are robust to different number of lags. The results remain robust to different ordering of variables and to alternate sample periods. Different ordering of the variables are tested by swapping position between the output and inflation or between the interest rate and monetary aggregate, etc.

1.5.2 Variance decomposition Analysis

This section offers the variance decomposition for the four small open economies whose impulse response functions are reported in section 1.5.1. Table 1 reports the contribution of money supply shocks and money demand shocks to exchange rate variations and for direct comparison table 2 reports the variance decomposition from the Bjornland original model setup.

Table 1								
Forecast Error Decomposition: Contribution of Money Supply (MS) Shocks and Money Demand (MD) Shocks to Exchange Rate Variation (in percentages)								
Quarters	Australia		New Zealand		Sweden		Canada	
	MS	MD	MS	MD	MS	MD	MS	MD
1	45	1	21	43	17	67	36	4
2	50	1	18	33	15	70	35	6.5
4	40	6	15	28	8	55	26	13
8	24	13	8	25	4	33	24	17
16	12	15	3	35	2	26	10	15
24	8	16	2	44	2	25	5	14

For majority of forecast horizon, monetary policy explains more of exchange rate variance as compared to Bjornland model. Money acts as an informational variable (thereby rightly capturing the information about the flow of monetary services in the economy) in helping interest rate explain more of exchange rate variation and for Sweden's case, it has a causal role.

Table 2				
Forecast Error Decomposition: Contribution of Money Supply Shocks to Exchange Rate Variation (in percentages)				
Quarters	Australia	New Zealand	Sweden	Canada
1	39	12	16	35
2	44	11	17	36
4	36	10	9	30
8	24	6	4	31
16	13	3	2	15
24	8	2	2	7

In Bjornland's model (table 2) Australian monetary policy plays a much more important role in

explaining the exchange rate variation as compared to other countries. The same pattern is witnessed in our model (table 1) but with a more amplified effect. For Australia the monetary policy is now explaining 45% variance in exchange rates in the 1st quarter which even increases to 50% in the next quarter. In the 4th quarter following the monetary policy shock, the policy variable still explains 40% of the variance in exchange rates. Interestingly, 12% of the exchange rate fluctuation is still explained by the interest rate, 16 quarters after the monetary policy shock hit the system. From table 2, the monetary policy explains 39% variance in exchange rates in the first quarter, 44% in the next quarter and 35% in the 4th quarter. Hence in our model the Australian monetary policy shock explains more of exchange rate variations in the initial quarters compared to Bjornland's model, which enables the model to correctly capture the on impact responses of exchange rates to a monetary policy shock as given in figure 1. From the variance decomposition analysis we believe that the Australian monetary aggregate mostly play the role of an informational variable thereby facilitating policy rate to explain higher percentage of the exchange rate fluctuation. In addition to money supply shocks, money demand shock also plays a significant role in explaining the exchange rate variation with its role becoming more important for later quarters. Initially the money demand shock for Australia does not contribute much by itself but its contribution keeps increasing for future forecast horizons with contribution up to 16% in 24th quarter.

Similarly for New Zealand, interest rate explains about 21%, 18% and 15% of the exchange rate fluctuation in the 1st, 2nd and 3rd, respectively, as compared to 12%, 11% and 10% from table 2. The model with money demand enables New Zealand's monetary policy to explain remarkably more of exchange rate variations as compared to the model without it. On the other hand, the money demand shock by itself plays the most important role for New Zealand. It explains 43% of

the exchange rate variation in the 1st quarter before decreasing slightly in the next two quarters. Eventually it picks up and is able to explain up to 44% in the final period of the analysis confirming the causal role associated with the monetary aggregate variable.

For Canada, interest rate explains about 36% of the exchange rate fluctuation in the 1st quarter. The monetary policy shock consistently explains a very high percentage of exchange rate variation till the 8th quarter and is still able to explain 10% percentage of variation in the 16th quarter. A similar trend for Canadian monetary policy is captured by the Bjornland model. The money demand shock starting from a moderate 4% in the 1st quarter, gradually increases to 17% in the 8th quarter in explaining the real exchange rate variation and is still able to explain up to 14% in the last quarter. This explains the role reversal of monetary aggregates from informational to causal variable at the end of the sample (after 16th quarter) like Australia.

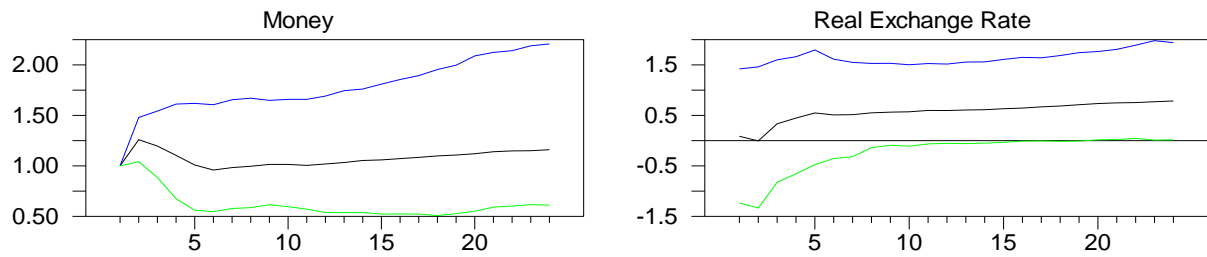
Sweden's M1 series starts from 1998, which makes estimation of quarterly SVAR impossible due to a small sample. It is established in many empirical studies that narrower monetary aggregate works better for such analyses. The broader monetary aggregate M3 is used for Sweden in the money demand equation, unlike M1 money for other countries. Sweden's M1 series starts from 1998, which makes estimation of quarterly SVAR impossible due to a small sample. It is established in many empirical studies that narrower monetary aggregate works better for such analyses. Therefore we present the results with M3 money for Sweden. On impact to a monetary policy shock, there is not much difference between our model vis-a-vis models by Bjornland in terms of variance decomposition. However money demand with broader monetary aggregates plays a role of causal variable explaining 67%, 70%, 55% of the exchange rate fluctuations in the 1st, 2nd and 4th quarters, respectively and still explaining 25% of the volatilities in the 24th quarter.

Figure 5 shows the direct effect of money demand shock on real exchange rates for all the four

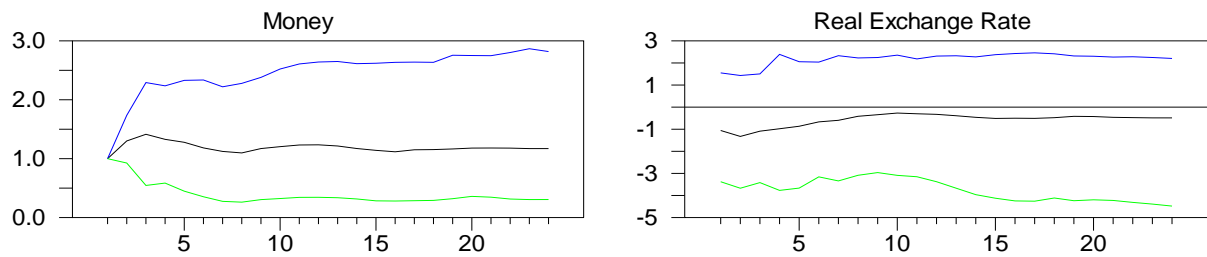
countries. Clearly, money demand shock does have a sizeable and significant effect on real exchange rates for all the countries except Sweden. The focus of this paper is not to talk about the direction of effect of money demand shock on exchange rate and we will refrain from making detailed discussions on this. The model estimated a highly persistent money demand shock leading to a long term significant effect on real exchange rate for Australia, Canada and New Zealand. Real exchange rate depreciates significantly after a money demand shock hits the economy. For Australia the depreciation of exchange rate starts becoming significant right before the 9th quarter whereas for New Zealand the depreciation of real exchange rate is significant throughout. Canadian exchange rate also depreciates with a money demand shock but the significance is achieved after 4th quarter. However, the money demand shock in Sweden causes an initial (insignificant) appreciation of real exchange rate before it starts (insignificantly) depreciating. We suspect that the availability of M1 data for Sweden would have produced more significant response of exchange rate to money demand shock. Hence, the qualitative effect of a money demand shock on real exchange rates and other macroeconomic variables like prices and output deserve a thorough analysis. The estimated impulse response function in figure 5 rationalizes the inclusion of monetary aggregates in SVAR analyses of monetary policy and exchange rates.

Figure 5: Effect of a unit Money Demand shock on Real Exchange Rate

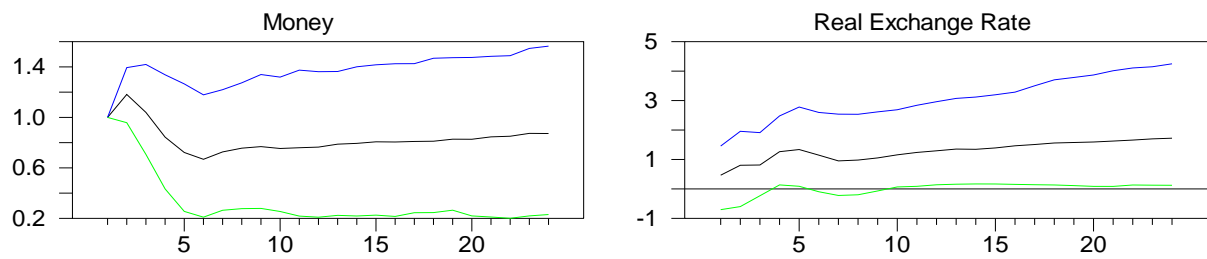
Australia



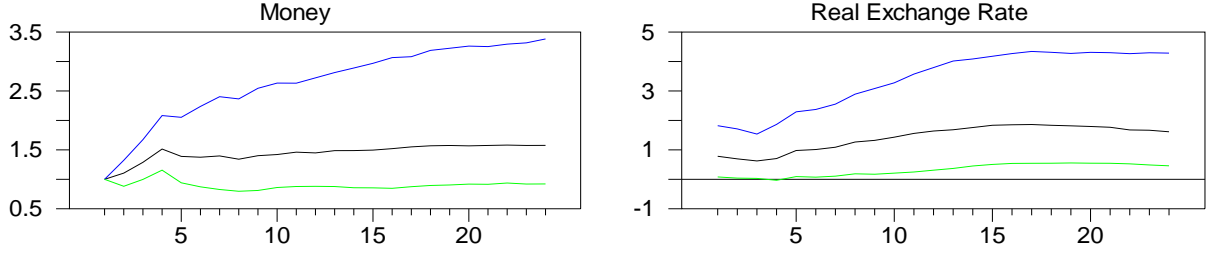
Sweden



Canada



New Zealand



1.5.3 Forecast statistics for exchange rate

In this section we try to compare our model including money demand vis-a-vis Bjornland's original model in terms of its ability to perform out-of-sample forecasts of exchange rates. Notice that our purpose in this section is not to find the best forecasting model. Instead we want to check if the forecasting performance of the model changes substantially when we add money to the system for the small open economies.

The forecasting performance of a model is assessed in terms of criteria, which are based on forecast errors. The criteria used are Root Mean Square Error (RMSE) and Theil U. The out-of-sample forecasting performance are evaluated using the Univariate OLS, Univariate BVAR, Simple BVAR and OLS VAR for Australia, Canada, Sweden and New Zealand. However in this paper we report the out-of-sample forecasting values using the simple Bayesian VAR model. The choice of the sample is driven by the Bjornland (2009) analysis, which ends at 2002:4. The eight-step out-of-sample update is done from the period 2002:4 to 2004:4 (8 steps). Forecast performance statistics (RMSE and Theil U) is compiled over that period and are given by the following formulas,

$$e_{it} = y_t - \hat{y}_{it}, \quad (1.25)$$

where \hat{y}_{it} is the forecast at step t from the i^{th} call, and y_t is the observed value of the dependent variable. Let N_t be the number of times that a forecast has been computed for horizon t , with $i = 1, 2, \dots, N_t$. Then the Room Mean Square Error of the forecasts is

$$RMSE_t = \sqrt{\frac{\sum_{i=1}^{N_t} e_{it}^2}{N_t}}. \quad (1.26)$$

In contrast, the RMSE of the no-change (martingale) forecasts are

$$RMSENCF_t = \sqrt{\frac{\sum_{i=1}^{N_t} (y_{it} - y_{i0})^2}{N_t}}, \quad (1.27)$$

where y_{i0} is the “naive” or flat forecast --- the value of the dependent variable at the start period for the i^{th} call.

Theil’s U statistic (Doan (2013)) is $U_t = \frac{RMSE_t}{RMSENCF_t}$, (1.28)

Theil’s U (see Doan, 2013) is a unit free measurement used for comparing forecasting models. A value less than one (but not substantially less than one) indicates that we have a good forecasting model.

Table 3: Forecast statistics for Exchange rate using simple Bayesian VAR (Australia)

Step	RMSE (No Money)	Theil U(No Money)	RMSE (Money)	Theil U(Money)
1	4.525440276	1.017387485	4.171557591	0.9378293
2	7.808663202	1.032864543	7.158846438	0.946912226
3	10.06481255	1.030794696	9.095953439	0.931568324
4	12.61735079	1.023370531	11.01519366	0.89342246
5	14.67781045	1.038436846	12.61785734	0.892697724
6	14.35331248	1.061301744	11.87042548	0.877713996
7	16.71060496	1.048031047	14.1091282	0.884875469
8	20.65224513	1.041707869	18.69177982	0.94282118

Table 3 compares the model with no money versus model with simple-sum M1 for Australia with 8- step ahead forecasts. We estimate the model through 1987:1 to 2002:4 with out-of-sample update from 2002:4 to 2004:4. **The model with money produces both lower RMSE and Theil U values than the Bjornland model.** More importantly the model with money produces Theil U values, which are consistently less than one.

Table 4: Forecast statistics for Exchange rate using simple Bayesian VAR (Canada)

Step	RMSE(No Money)	Theil U(No Money)	RMSE(Money)	Theil U(Money)
1	4.251447335	1.056287954	4.241706736	1.053867866
2	7.569683062	1.144901894	7.562240258	1.143776183
3	9.051277267	1.215142196	9.023920935	1.211469584
4	11.33791435	1.270549682	11.31338534	1.267800912
5	13.61197605	1.392793015	13.58786022	1.390325455
6	16.45618489	1.458586159	16.41324153	1.454779895
7	24.07915593	1.478452017	24.06738473	1.47772927
8	32.50365936	1.545158132	32.54509543	1.547127919

Table 4 compares the model with no money versus model with simple-sum M1 for Canada with 8- step ahead forecasts. We estimate the model through 1987:4 to 2002:4 with out-of-sample update from 2002:4 to 2004:4. **The model with money does better than the model with no money in terms of producing lower RMSE and Theil U values.** However notice that both the model with/without money are not producing the best result forecasting results. This is clear from the Theil U values greater than one at all forecasting horizon.

Table 5: Forecast statistics for Exchange rate using simple Bayesian VAR (New Zealand)

Step	RMSE(No Money)	Theil U(No Money)	RMSE(Money)	Theil U(Money)
1	3.392591796	0.925213259	3.460717569	0.943792231
2	4.018806318	0.854263961	4.122909682	0.876392858
3	4.258503529	0.752849637	4.396755644	0.777290865
4	5.789129791	0.746314084	5.904446828	0.761180347
5	8.160684979	0.8117552	8.573537686	0.852822259
6	7.939364429	0.763642232	8.439107615	0.811709682
7	9.540840004	0.71815069	10.24952765	0.771494475
8	14.38153861	0.80159341	15.9677646	0.890005946

Table 5 compares the model with no money versus model with simple-sum M1 for New Zealand with 8- step ahead forecasts. We estimate the model through 1990:1 to 2002:4 with out-of-sample update from 2002:4 to 2004:4. **The model with no money produces lower RMSE and Theil U values than the model with simple-sum M1.** However both the models are showing decent out-of-sample forecasting performance in terms of producing Theil U values less than one.

Table 6: Forecast statistics for Exchange rate using Simple Bayesian VAR (Sweden)

Step	RMSE(No Money)	Theil U(No Money)	RMSE(Money)	Theil U(Money)
1	1.994566094	1.157886097	1.974467684	1.146218562
2	2.91035546	1.347197187	2.898067192	1.341508974
3	3.644178658	1.54649909	3.71280019	1.575620367
4	4.688405351	1.771274434	4.799578296	1.813275452
5	5.642664265	2.554222399	5.769139489	2.611472987
6	6.431503614	3.946744125	6.750316944	4.1423865
7	8.49246809	3.108760682	8.931479435	3.269465579
8	11.85950264	2.601227826	12.30712126	2.699407154

Table 6 compares the model with no money versus model with simple-sum M3 for Sweden with 8- step ahead forecasts. We estimate the model through 1988:1 to 2002:4 with out-of-sample

update from 2002:4 to 2004:4. The Bjornland model does slightly better than the model with money in terms of producing lower RMSE and Theil U values. More importantly both the models are producing Theil U values, which are consistently greater than one. **We suspect availability of narrower simple-sum monetary aggregate for Sweden might have improved the forecasting performance of the model with money.**

1.6 Conclusion

Dornbusch's exchange rate overshooting marks the birth of the modern international economics. Surprisingly studies of monetary policy have typically found exchange rate effects inconsistent with overshooting (Eichenbaum and Evans, 1995; Grilli and Roubini, 1997; Sims, 1992). Bjornland (2009) finds evidence of exchange rate overshooting for four small open economies: Australia, Canada, Sweden and New Zealand. However, correct monetary policy identification requires understanding both central bank's reaction to economic condition and private sector response to policy action.

Alternative to Bjornland (2009), both money supply and money demand are used to correctly identify the monetary policy shock. A combination of short-run and long-run restriction is used to obtain an exact-identified system. Additionally a two-country theoretical framework has been introduced to illustrate the specific characteristics of monetary policy making in a small, open economy. The short-run identification restrictions in the model are derived from theoretical framework. Alternative to Bjornland, the error bands are generated using the lag sum of coefficients drawn from the Monte Carlo procedure. We find evidence of significant exchange rate overshooting using the corrected error bands.

A direct comparison is offered between our model result and Bjornland's finding. For majority

subsamples, the current model restriction does substantially better and in some cases at least as good as Bjornland (2009). In fact the new set-up generates impulse response functions (IRFs) graphs, which closely resemble original Bjornland result. Additionally significant and tighter bands for the impulse response of the exchange rate to monetary policy shock is obtained. This explains why monetary models of exchange rates should have both the money demand and money supply equations to capture the dynamics of money market instead of having interest rate alone as the monetary policy instrument. This is also supported by variance decomposition (VD) analysis, which shows when monetary aggregates are introduced in the model, money market equilibrium conditions are captured better. The results further show that monetary aggregate alternatively plays both ‘causal’ and ‘informational’ role for Australia, Canada, Sweden and New Zealand. An additional out-of-sample forecasting performance is done in the paper for robustness check.

Chapter 2: An SVAR Approach to Evaluation of Monetary Policy in India: Solution to the Exchange Rate Puzzles in an Open Economy

2.1 Introduction

Post 2008-crisis has witnessed a series of unconventional monetary policies. Such unconventional monetary policies may not be correctly modeled by the usual policy measures. It could be misleading to measure the impact of monetary policy and to track the monetary policy transmission mechanism solely through interest rates, especially when the rates are near zero. In zero lower bound environments, we find the need for an additional monetary indicator to be particularly relevant in

monetary models of exchange rate determination. A theoretically grounded and properly measured indicator of money (the Divisia monetary aggregate) is a measure that can help trace the monetary transmission mechanism of unconventional policy stances by central banks. The Divisia monetary aggregates are provided for the United States by the Center for Financial Stability in New York City. We apply the Divisia monetary aggregate data available for India.

In the majority of exchange rate studies, interest rates alone plays the role of the monetary policy instrument. But Chrystal and McDonald (1995) have observed that the breakdown of the monetary models of exchange rates is associated with the troubling behavior of the simple-sum monetary aggregates.⁷ In this paper we emphasize the need to bring monetary aggregates back into the exchange rate models, but with better measures of money than the simple-sum accounting measures having no foundations in microeconomic aggregation theory. The following contributions are relevant. Ireland (2001a, 2001b) finds empirical support for including money growth in an interest rule for policy. In Ireland's model, money plays an informational rather than a causal role by helping to forecast future nominal interest rate. Other papers emphasizing the “information content” of monetary aggregates in predicting inflation and output include Masuch et al. (2003) and Bruggeman et al. (2005).⁸

⁷ The velocity of M1, which had been stable since 1945, suddenly took a sharp downward trend after 1980 (Stone and Thornton (1987)). Leeper and Roush (2003) agree with Chrystal and McDonald that traditionally stable money demand functions were widely perceived to have become unstable.

⁸ Nelson (2003) offers an alternative role for money. He argues that money demand depends on a long-term interest rate.

Nelson's resulting specification of the Federal Reserve's interest rate rule is a dynamic generalization of the conventional Taylor rule, which excludes money. Money now has a direct effect that is independent of the short-term interest rate.

Recently there has been growing interest in the use of monetary aggregates in “nowcasting” nominal GDP (gross domestic product), especially in the context of proposals for nominal GDP targeting. See, e.g., Barnett, Chauvet, and Leiva-Leon (2015). The Federal Reserve does not have monthly contemporaneous information on output, but it does have monthly observations on the money stock. Hence money may help the Federal Reserve infer current values of GDP. In particular, Barnett, Chauvet, and Leiva-Leon (2015) found a Divisia monetary aggregate to be a highly significant indicator that can be used among others to produce very accurate nowcasts of nominal GDP.

Goodfriend (1999) argues that money plays a critical role, even under an interest rate instrument policy, because credibility for a price-path target depends upon the central bank's ability to manage the stock of money to enforce the objective. In equilibrium, money does not play a causal role in Goodfriend's view, but is essential for establishing the credibility that allows the central bank to determine expected inflation. Similar positions have been taken by such authors as Christiano et al. (2007) and Cochrane (2007). For example, Cochrane (2007) argues that monetary aggregates may play a nominal anchor role, whereby the announcement of a reference trajectory for future monetary growth may help agents form expectations about future prices. In comparisons among models without money and models with interactions between money and the funds rate, Leeper and Roush

Nelson concludes that the effect is consistent with U.S. data. Anderson and Kavajecz (1994) argued for the use of monetary aggregates as either indicators and/or targets of monetary policy. Several more recent studies, such as Nicoletti-Altimari (2001), Trecoci and Vega (2002), Jansen (2004), and Assenmacher-Wesche and Gerlach (2006), have found a useful leading indicator role for monetary and credit aggregates with respect to low-frequency trends in inflation.

(2003) have found large and significant effects of money on the estimated real and nominal effects of policy. Hence money provides information important to identifying monetary policy-transmission not contained solely in the Federal fund rate.

One of this paper's contributions is to introduce the theoretically grounded Divisia monetary aggregate into the Kim and Roubini (2000) setup. Divisia monetary aggregates are directly derived from microeconomic aggregation theory, as shown by Barnett (1980), and are consistent with Diewert's (1976) criteria for inclusion in the "superlative index number class." Divisia monetary aggregates measure the flow of the monetary services derived from a collection of monetary assets, while permitting those component assets to be imperfectly substitutable, as compared to the simple sum aggregates, which assume all monetary assets to be perfectly substitutable. A large literature exists on the empirical and theoretical merits of those aggregation theoretic aggregates. See, e.g., Barnett and Serletis (2000), Barnett and Chauvet (2011), and Barnett (2012), along with Schunk (2001), Drake and Mills (2005), Chrystal and McDonald (1995), and Belongia and Ireland (2012), among many others. Of particular relevance is Barnett and Kwag (2006), who find that introducing Divisia aggregates into money market equilibrium conditions improves the forecasting performance of monetary models of exchange rates. A source of much of that literature is the online library maintained by the Center for Financial Stability in New York City at <http://www.centerforfinancialstability.org/amfm.php>.

Almost 15 years post publication of Kim and Roubini (2000), we revisit similar small open economy structural vector auto-regression (SVAR) models. But we do so with data from India: an economy that is relatively open, one of the biggest importers of oil, on the transition path to becoming one of the emerging Asian economies, a member of the G20 nations, and governed by a central bank that

avoids intervening heavily in the foreign exchange market. Our model builds on the Kim and Roubini (2000) model and is customized for the Indian economy.

The paper examines the impact of monetary policy shocks on the price level, output, and exchange rate. In particular, we explore whether monetary policy shocks have a delayed and gradual effect on the price levels, whether a shock to the policy has a small and temporary or a substantive and permanent effect on the output, and whether monetary policy serves to dampen output and price fluctuation for the Indian economy. Finally we explore whether there is existence of delayed exchange rate overshooting. The interest rate equation in our model is the policy reaction function of the central bank with the money/interbank rate for India being the interest rate. The monetary aggregate equation is a money demand equation, dependent upon output, price, and interest rates.

We compare across models that contain no money, with interbank rates of interest being the only monetary policy variable. Then we add simple-sum money into our model along with the policy rate variables, and finally Divisia money. We extensively compare across these three sets of models. We also compare across the monetary models at different levels of aggregation.

We also provide a variance decomposition analysis. For models with money, especially Divisia money, the policy variable is found to explain more of the exchange rate fluctuation than the models containing simple-sum money or the models without money. Finally, we test the out-of-sample forecasting power of the different models.

Our result shows that the models with monetary aggregates perform significantly better than the no-money models, and that models with the Divisia monetary aggregate outperform their simple-sum counterpart.

2.2 The Indian Economy at a Glance

The following figures provide a brief overview of the Indian economy since 1992.

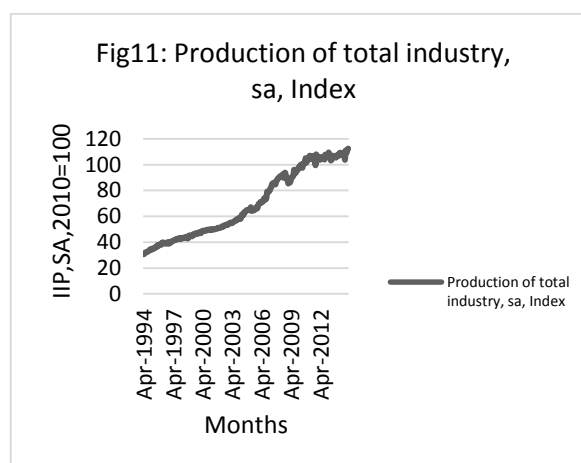
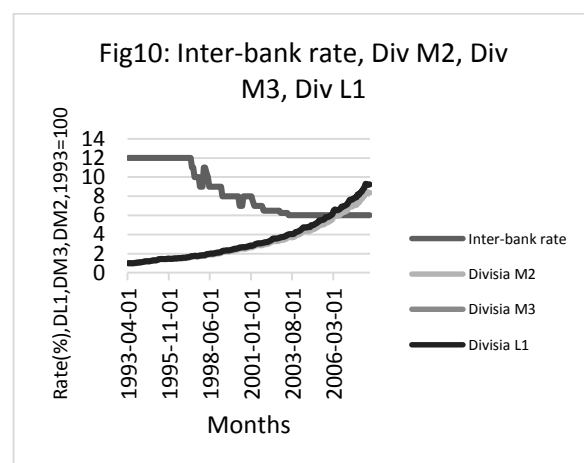
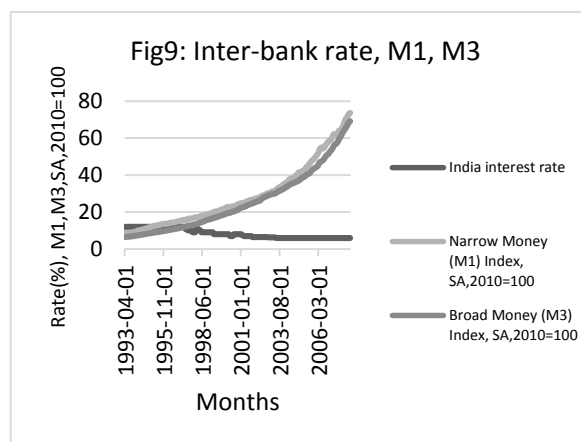
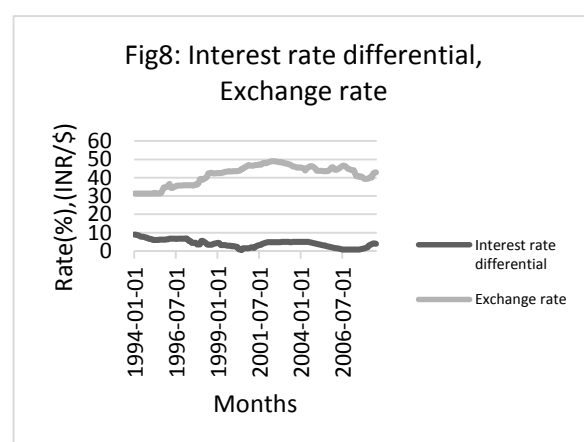
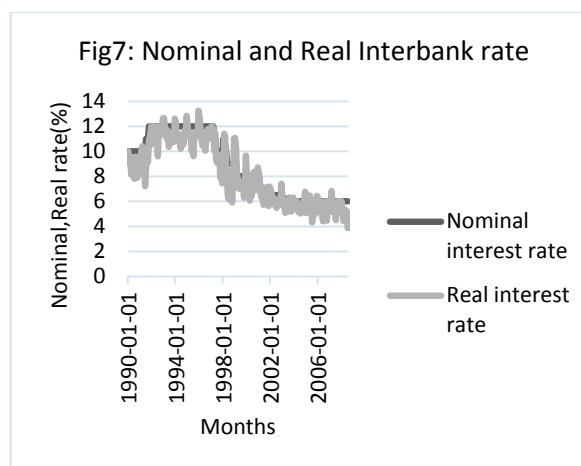
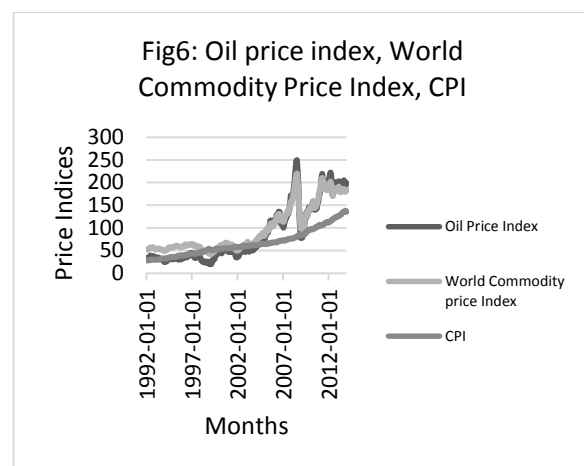


Figure 6 shows the Indian economy experienced very high inflation during the last 24 years. The CPI (consumer price index) between the first quarter of 1992 and the last quarter of 2013 rose by 384 percent. The average was a 17 percent price rise. However, from the first quarter of 1992 to the first quarter of 2000, CPI rose by 89%. On an average, there was a 9 percent price rise every year during that time period.

Figure 7 shows that loose monetary stance was a dominant feature of the economy between 1992 and 1997.

Figure 8 displays the interest rate differential between India and U.S. and the exchange rate of the India rupee relative to the US dollar. The figure suggests that the movements of the nominal exchange rate appear to have followed the interest rate differential with a lag.

Figure 9 displays the accelerated growth in the money supply for both M1 and M3 during a period of loosening of inter-bank rates.

Figure 10 displays the liquidity of the Indian economy using the theoretically grounded Divisia monetary aggregates. Divisia reflects much liquidity injection into the economy, but not as much as the simple-sum monetary aggregates would imply.

Figure 11 displays the production of total industry (IIP) for India. The period of highest industrial growth was between 2002 and 2007, after which the growth slowed dramatically.

2.3 Estimation

2.3.1. Model

The system of equations representing the SVAR dynamic structural models can be written in terms of the p -th order structural VAR model is written as

$$C(L)y_t = v_t \quad (2.1)$$

where, $Ev_t v_t' = G$
and $Ev_t v_{t+s}' = 0, \forall s \neq 0$

$C(L)$ is the p -th order matrix polynomial in the lag operator L and $C(L)$ can be written as follows: $C(L) = C_0 - C_1 L - C_2 L^2 - \dots - C_p L^p$. C_0 is a non-singular matrix with the diagonal elements normalized to one. C_0 summarizes the contemporaneous relationship between the model variables and the identification restrictions are imposed on C_0 ; y_t is an $n \times 1$ vector, v_t is an $n \times 1$ structural disturbances vector. The disturbances v_t are serially and mutually uncorrelated, while p denotes the number of lags. The matrix C_0 is defined by

$$C_0 = \begin{bmatrix} 1 & -C_{12}^{(0)} & \dots & -C_{1n}^{(0)} \\ \vdots & \vdots & \dots & \vdots \\ \vdots & \vdots & \dots & \vdots \\ -C_{n1}^{(0)} & -C_{n2}^{(0)} & \dots & 1 \end{bmatrix} \quad (2.2)$$

while C_t is an $n \times n$ matrix whose row i , column j element is $C_{ij}^{(s)}$ for $s = 1, 2, \dots, p$.

The reduced form representation of the structured model is as follows.

$$\begin{aligned} B(L)y_t &= \varepsilon_t \\ E\varepsilon_t \varepsilon_t' &= \Sigma \\ E\varepsilon_t \varepsilon_{t+s}' &= 0, \forall s \neq 0 \end{aligned} \quad (2.3)$$

$$\text{where, } B(L) = C_0^{-1} C(L) \quad (2.4)$$

Thus the VAR, equation (2.3), can be viewed as the reduced form of the dynamic structural model, (2.1). The structural disturbances, v_t , and the reduced form residuals, ε_t , are related by

$$\text{and } \varepsilon_t = C_0^{-1} v_t \quad (2.5)$$

To estimate the parameters from the structural form equations requires that the model be either exactly identified or over-identified. A necessary condition for exact identification is that there be the same number of parameters in C_0 and G as in Σ , where $G = E(v_t v_t')$ is the covariance matrix of the structural disturbances, and $\Sigma = E(\varepsilon_t \varepsilon_t')$ is the covariance matrix of the reduced form disturbances, ε_t . Under this condition, called the order condition, it is possible to recover the structural parameters from the reduced form. In addition the model must satisfy the rank condition, as can be assured by using the Cholesky decomposition of the reduced form innovations, as proposed by Sims (1980). The result is a recursive structure identifying the model. There are other methods, such as structural VAR, which can be non-recursive, with restrictions imposed on instantaneous relations among the variables. Those restrictions can come from economic theory (see, e.g., Bernanke (1986)).

The following results from the above definitions:

$$\Sigma = E(\varepsilon_t \varepsilon_t') = C_0^{-1} E(v_t v_t') (C_0^{-1})' = C_0^{-1} G (C_0^{-1})'. \quad (2.6)$$

Since Σ is symmetric, it has $\frac{n(n+1)}{2}$ parameters. In the SVAR literature, G is the diagonal matrix

having n parameters. Hence C_0 can have no more than $\frac{n(n-1)}{2}$ restrictions for exact identification

and is a triangular matrix for the VAR with Cholesky decomposition of the innovations.

For an exactly identified model, a two-step maximum likelihood estimation procedure can be employed under the assumption that the structural errors are multivariate normal. The procedure results in full information maximum likelihood (FIML) estimation of the SVAR model. First, Σ is estimated as

$$\hat{\Sigma} = (1/T) \sum_{t=1}^T \hat{\mathbf{e}}_t \hat{\mathbf{e}}_t', \quad (2.7)$$

with $\hat{\mathbf{e}}_t$ being the estimated residuals. Estimates of C_0 and G are then obtained by maximizing the

log likelihood, conditional on $\hat{\Sigma}$. But when the model is over-identified, the two-step procedure does not produce the FIML estimator for the SVAR model. The two-step estimates are consistent but not efficient, since they do not take the over-identification restrictions into account, when estimating the reduced form. For an over-identified system, we estimate the VAR model both without additional restrictions and with additional restrictions to obtain the ‘unrestricted’ and ‘restricted’ variance-covariance matrices, respectively. In each case, we maximize the likelihood function. The difference between the determinants of the restricted and unrestricted variance-covariance matrices is distributed χ^2 with degrees of freedom equal to the number of additional restrictions resulting from exceeding the just identified system. The χ^2 test statistic is used to test the restricted system. (see, e.g., Hamilton (1994)).

Ideally, the restrictions imposed to identify a SVAR model would result from a fully specified macroeconomic model. In practice, however, this is rarely done. Instead, the more common approach is to impose a set of identification restrictions that are broadly consistent with the economic theories and provide sensible outcomes. Generally, the metric used is whether the behavior of the dynamic responses of the model accords with the economic theories. Given a set of variables of interest and criteria for model selection, identification restrictions can be imposed in a number of available ways. Most commonly, these involve restrictions on C_0 or on C_0^{-1} , or restrictions on the long run behavior of the model.

2.3.2 Identification

We use a 7-variable VAR including the world oil price index and alternatively the commodity price index (oilp or wpcom), the federal fund rate (rfed), the India index of industrial production (iip), the level of inflation in the domestic small open economy (π), a domestic monetary aggregate (MD), nominal short-term domestic interest rate (rdom) producing the monetary policy shocks (MP), and the nominal exchange rate in domestic currency per US dollar (ER).⁹ Our identification scheme based on equation (3.7) is given below.

⁹Differencing of variables does not provide gain in asymptotic efficiency and may cause loss of information regarding the co-movements, such as cointegrating relationships between variables. Hence, we use a VAR in levels.

$$\begin{pmatrix} v_t^{oil \text{ or } wcom} \\ v_t^{rfed} \\ v_t^{iip} \\ v_t^\pi \\ v_t^{MD} \\ v_t^{MP} \\ v_t^{ER} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ c_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ c_{31} & c_{32} & 1 & 0 & 0 & 0 & 0 \\ c_{41} & 0 & c_{43} & 1 & 0 & 0 & 0 \\ 0 & c_{52} & c_{53} & c_{54} & 1 & c_{56} & c_{57} \\ c_{61} & 0 & 0 & 0 & c_{65} & 1 & c_{67} \\ c_{71} & c_{72} & c_{73} & c_{74} & c_{75} & c_{76} & 1 \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil \text{ or } wcom} \\ \varepsilon_t^{rfed} \\ \varepsilon_t^{iip} \\ \varepsilon_t^\pi \\ \varepsilon_t^{MD} \\ \varepsilon_t^{MP} \\ \varepsilon_t^{ER} \end{pmatrix} \quad (2.8)$$

Here v_t is the vector of structural innovations, while ε_t is the vector of errors from the reduced form equations. This specification is similar to Kim and Roubini (2000), but modified to fit the Indian economy better and to permit comparisons of different monetary aggregates.

Restrictions on C_0 are motivated in the following way. As in Kim and Roubini (2000), we have a contemporaneously exogenous world shock variable, alternatively captured using the world commodity price index and world price index. Although none of the domestic variables can affect the world variables contemporaneously, they can do so over the time. Similarly, the federal funds rate in the U.S. is only affected by the world event shocks. No domestic events have enough impact to influence the policy variables of the largest economy in the world. As in Kim and Roubini (2000), it is necessary to include these two variables to isolate and control the exogenous component of monetary policy shocks.

A further behavioral restriction often imposed is that certain variables respond slowly to movements in financial and policy variables. So, for example, output and prices do not respond contemporaneously to changes in domestic monetary policy variables and exchange rates. Real activity, like industrial production, responds to domestic price and financial signals with a lag, as a result of high adjustment costs to production. However, industrial production of a small, open, economy is deeply impacted by world or outside shocks. Inflation and industrial production are

affected by the world shock. People's willingness to hold cash given by the money demand function usually depends on real income and the domestic interest rate. To explore how different monetary aggregates compare in identifying the monetary policy for a small open economy and how they contribute to explaining the exchange rate movements, we assume that the money demand function also depends on the foreign (US) interest rate and the prevailing exchange rates. The monetary policy equation is the monetary authority's reaction function, which sets the interest rate after observing the current value of money supply, the interest rate, and the exchange rate.

The Liquidity Adjustment Facility (LAF) was introduced by the Reserve Bank of India (R.B.I) for the first time from 2000 onward, on the basis of the recommendations of the second Narsimham Committee. The induction of LAF helped to develop interest rate as an instrument of monetary policy transmission. In our paper, the domestic short term nominal interest rate is chosen to produce monetary policy shocks. In order to identify and estimate the impact of policy change, we needed to choose the sample period meticulously. The choice of the sample period starting in January 2000 acknowledges the paradigm change in monetary framework of the R.B.I. This framework was reinforced in May 2011, when the weighted average overnight call money rate was explicitly recognized as the operating target of the monetary policy.

The data are in monthly frequency for the sample period January 2000- January 2008. The foreign crude oil price index is an arithmetic average of three spot prices; Brent, West Texas Intermediate, and Dubai Fateh, obtained from the database of Index Mundi. All commodity price indexes, fuel and non-fuel, and IMF commodities are obtained from the Econ Stats website. The Indian variables --- the index of total industry production, the consumer price index, the interest rate (call money\interbank rate), the simple-sum monetary aggregate indexes (M1) and (M3), and the nominal exchange rate (Indian rupee per USD) --- along with the US federal funds rate, are obtained from the

OECD database.¹⁰ The Divisia monetary aggregates, (DM2), (DM3), and (DL1), are obtained from Ramachandran, Das, and Bhoi (2010) (RDB). Our analysis of monetary policy for the Indian economy was subject to availability of the Divisia data published by (RDB) and the simple sum monetary aggregate published by OECD.

The series are seasonally adjusted by the official sources except for the Indian Divisia, the world oil prices, and the world price of commodities, which are seasonally adjusted using frequency domain deseasonalization in RATS (see Doan (2013)). All variables are in logarithms except for the interest rates. The inflation (π) is calculated as the annual change in the log of consumer prices. Monthly VAR is estimated using 6 lags. The lags are selected by the sequential likelihood ratio test in RATS (see Doan (2013)). The main results of the paper remain unchanged and robust to the use of different numbers of lags. This shows that the models do not have any degrees of freedom problems with the use of six lags. The results from sequential likelihood ratio test are presented in table A in the appendix.

2.4 Empirical Results

2.4.1 Impulse Response Analysis

¹⁰ The Indian monetary aggregates are defined as follows: M2 = currency with the public + demand deposits with banks + other deposits with the Reserve Bank of India + savings deposits with banks + term deposits with contractual maturity of up to and including one year with banks + certificate of deposits issued by banks; M3 = M2 + term deposits with contractual maturity of over one year with banks + call borrowings from non-depository financial corporations by banks; and L1 = M3 + all deposits with the Post Office Savings Banks (excluding National Savings Certificates).

We evaluate the models given in Table 7 relative to the four prevalent puzzles that have plagued the empirical exchange rate literature: namely, the liquidity puzzle, the price puzzle, the exchange rate puzzle, and the forward discount bias puzzle. In this section we also provide three impulse response graphs, one for the recursive model with no money (Model 16), the SVAR model with simple-sum M3 (Model 2), and the SVAR model with Divisia M3 (Model 1).¹¹

¹¹ The results with other models are available upon request.

Table 7: Recursive and Non-recursive Model Setup ¹²		
SVAR Model [Non-Recursive (NR) Structure]		
Model 1	{oilp, rfed, iip, π , DM3, rdom, ER}	(NR, OIL, DM3)
Model 2	{oilp, rfed, iip, π , M3, rdom, ER}	(NR, OIL, M3)
Model 3	{oilp, rfed, iip, π , M1, rdom, ER}	(NR, OIL, M1)
Model 4	{oilp, rfed, iip, π , DL1, rdom, ER}	(NR, OIL, DL1)
Model 5	{oilp, rfed, iip, π , DM2, rdom, ER}	(NR, OIL, DM2)
Model 6	{wcom, rfed, iip, π , DM3, rdom, ER}	(NR, COM, DM3)
Model 7	{wcom, rfed, iip, π , M3, rdom, ER}	(NR, COM, M3)
Model 8	{wcom, rfed, iip, π , M1, rdom, ER}	(NR, COM, M1)
Model 9	{wcom, rfed, iip, π , DL1, rdom, ER}	(NR, COM, DL1)
Model 10	{wcom, rfed, iip, π , DM2, rdom, ER}	(NR, COM, DM2)
VAR Models with Cholesky Decomposition [Recursive (R) Structure]		
Model 11	{oilp, rfed, iip, π , DM3, rdom, ER}	(R, OIL, DM3)
Model 12	{oilp, rfed, iip, π , M3, rdom, ER}	(R, OIL, M3)
Model 13	{oilp, rfed, iip, π , M1, rdom, ER}	(R, OIL, M1)
Model 14	{oilp, rfed, iip, π , DL1, rdom, ER}	(R, OIL, DL1)
Model 15	{oilp, rfed, iip, π , DM2, rdom, ER}	(R, OIL, DM2)
Model 16	{oilp, rfed, iip, π , rdom, ER}	(R, OIL, X)

We now briefly define the four puzzles that have been widely prevalent in the exchange rate literature:

(1) Theory predicts that an increase in the domestic interest rates should lead to an impact appreciation of the exchange rate (exchange rate overshooting) and thereafter depreciation of the currency in line with the uncovered interest parity. Higher return on investments from the increase in domestic interest rates would lead to a higher demand for domestic currency and hence appreciating of the domestic currency relative to the foreign currency. The *exchange rate puzzle* occurs when a restrictive domestic monetary policy leads to an impact depreciation of domestic currency.

(2) Alternatively, if the domestic currency appreciates, it does so for a prolonged period of time, violating the uncovered interest parity condition. That phenomenon is known as the *forward discount bias puzzle* or delayed overshooting.

(3) The *liquidity puzzle* results, when a money market shock is associated with increases in the interest rate. This phenomenon reflects the absence of the liquidity effect, defined by negative correlation between monetary aggregates and interest rates.

(4) The *price puzzle* is a phenomenon by which a contractionary monetary policy shock, identified with an increase in interest rates, leads to a persistent rise in price level.

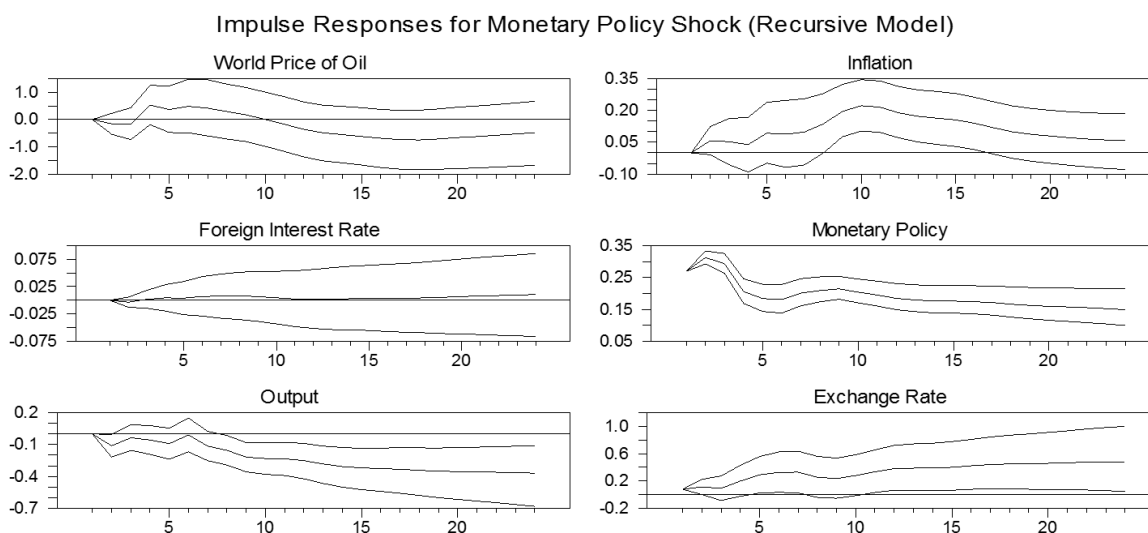
¹² The codes in parentheses represent the model structure (Non-Recursive or Recursive), the world variable (World price of oil or World Commodity price), and the monetary aggregate (DM3, M3, M1, DL1, DM2, or X, which designates no money).

Table 8 summarizes the main results that we obtain from models with Cholesky ordering and from the SVAR models.

Table 8: Model Setup Analysis in Terms of Puzzles				
Model & Code	Liquidity Puzzle	Price Puzzle	Exchange Rate Puzzle	Forward Discount Bias Puzzle
1 (NR,OIL,DM3)	Slight to none	None	None	None
2 (NR,OIL,M3)	Insignificant	None	Slight to None	None
3 (NR,OIL,M1)	Yes	Yes	None	None
4 (NR,OIL,DL1)	Slight to none	None	None	None
5 (NR,OIL,DM2)	Slight to none	None	None	None
6(NR,COM,DM3)	Slight to none	Slight to none	None	None
7 (NR,COM,M3)	Insignificant	Insignificant	None	None
8 (NR,COM,M1)	Insignificant	None	None	None
9 (NR,COM,DL1)	Insignificant	Insignificant	None	None
10(NR,COM,DM2)	Insignificant	None	None	None
11 (R,OIL,DM3)	Yes	Yes	Slight to None	Yes
12 (R,OIL,M3)	Insignificant	Yes	Yes	Yes
13 (R,OIL,M1)	None	Yes	Yes	Yes
14 (R,OIL,DL1)	Yes	Yes	Slight to None	Yes
15 (R,OIL,DM2)	Yes	Yes	Slight to None	Yes
16 (R,OIL,X)	Yes	Yes	Yes	Yes

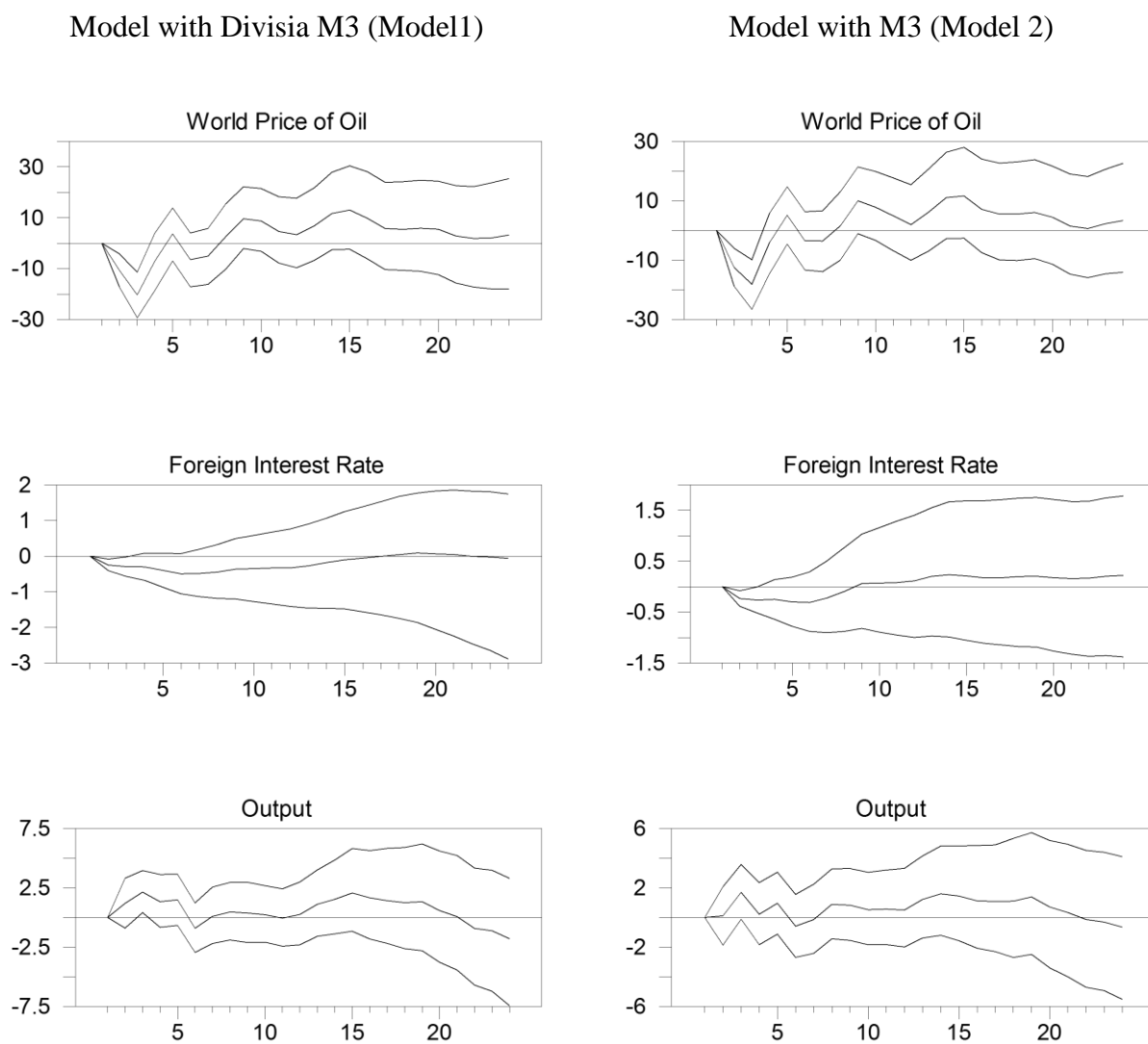
We encounter almost all the puzzles in the recursive models (models 11-16). Figure 12 displays the impulse response graphs for a recursive model with no money. The effect of monetary policy shocks is normalized, so that interest rates increase by one percentage point in the first month. A one percentage point increase in the interest rate leads to an impact depreciation of the currency and persistent depreciation thereafter, producing both the exchange rate puzzle and the forward discount bias puzzle. There is also a persistent rise in inflation from a contractionary monetary policy shocks, producing the price puzzle.

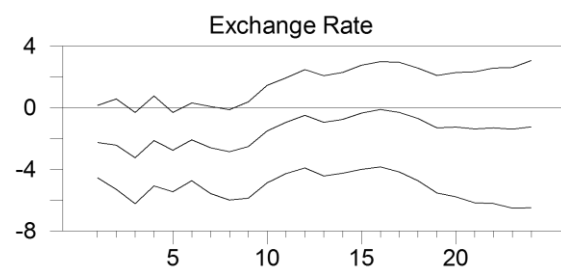
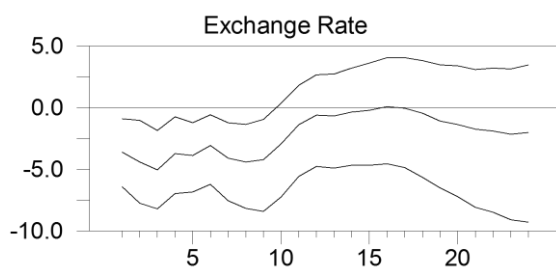
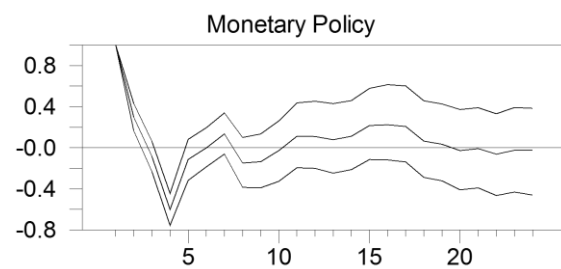
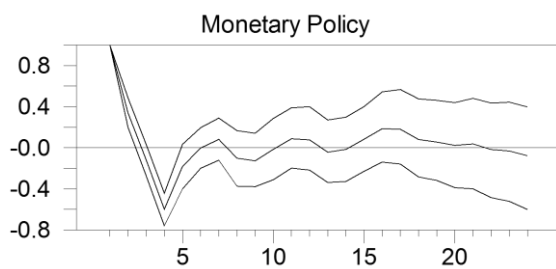
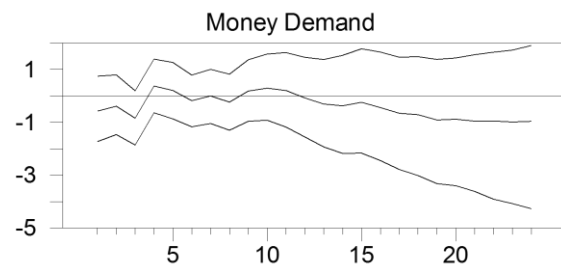
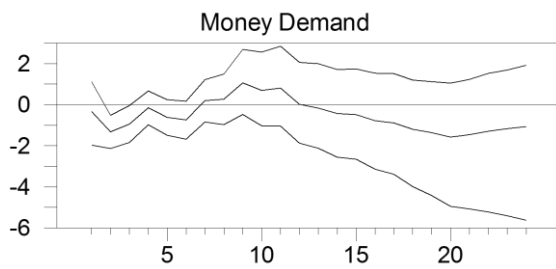
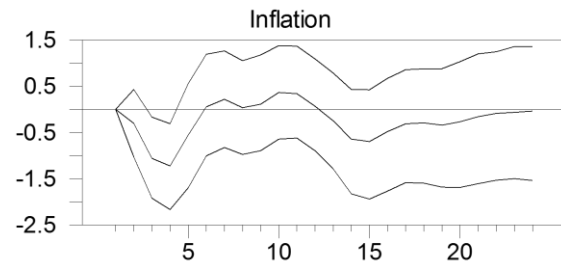
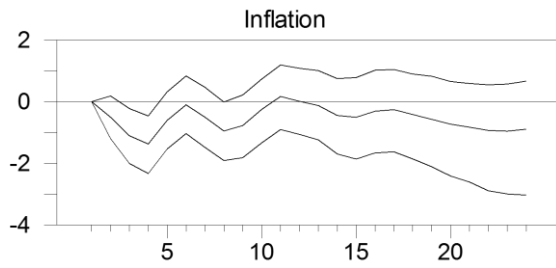
Figure 12: Impulse Responses for Monetary Policy Shocks (Recursive Model)



In contrast, the SVAR (non-recursive) models reflect the Indian monetary policy more acceptably. Most of the puzzles are eliminated, and the results are robust. We see the intensity of the liquidity effect. Exchange rate overshooting is more pronounced for the model with Divisia M3 than with simple sum M3.

Figure 13: Impulse Responses for Monetary Policy Shocks (Non-Recursive Model)





The statistical significance of impulse response is examined using the Bayesian Monte Carlo integration in RATS. The Random Walk Metropolis Hastings method is used to draw 10,000

replications for the over-identified SVAR model. The 0.16 and 0.84 fractiles correspond to the upper and lower dashed lines of the probability bands (see Doan (2013)).

From model 1, we observe monetary policy shocks have no initial impact on oil price. However, we subsequently observe growth in oil price, especially between the 10th and 15th month. The fact that major oil-importing countries, such as India, can influence price is not surprising. The domestic monetary policy shocks cannot affect the fed fund rate. Monetary policy shocks appear to have a short-lasting impact on industrial production. We observe a hump-response of industrial production to a monetary policy shock during the first 5 months. Since India's financial markets are not highly developed, the monetary transmission of financial signals into the real sectors of the economy is slow.

The literature on economic development has long argued that production shifts first from agriculture into manufacturing and – only at a later stage of development – from manufacturing into services. This is known as the Fisher-Clark-Kuznets hypothesis, which appears consistent with much cross-country evidence. However, the Indian growth experience has been unique in such a way that the services trade has expanded rapidly, while the decline in the share of agriculture in the economy has found its counterpart in services rather than manufacturing. This structure could account for the immune or delayed response of industrial production to a monetary policy shock. The contraction in monetary policy has kept the growth in prices or inflation consistently below zero. We observe exchange rate overshooting in response to a monetary policy shock. The exchange rate appreciates on impact, before beginning to depreciate.

In model 2, contractionary monetary policy shocks are followed by a slightly increasing trend in oil prices with effects peaking at the 10th and 15th months. During the first 8 months, monetary policy shocks have negligible impact on the federal fund rate, followed by increasing funds rate. The

response of industrial production to a monetary policy shock is insignificant. Following the shock, price growth remains initially negative, but positive price growth appears between the 6th and the 12th month. The impact of the policy shock seems to be short-lived. Following monetary policy shocks, money demand, measured using the simple-sum aggregates, exhibits mild growth with the effect peaking between the 10th and 14th months. Exchange rate appreciates following a monetary policy shock with delayed overshooting.

The SVAR models generally perform better than the recursive models, and models with the Divisia monetary aggregates perform better than models with the simple-sum monetary aggregates. We compare across Divisia M3 and simple-sum M3 with models including either the world price of oil or the world price of commodities. The Divisia results were better than the simple-sum results. This holds true for other available Indian Divisia aggregates. Relative to the four puzzles, Brischetto and Voss (1999) argue that resolving at least the price puzzle and exchange rate puzzle should be viewed as the minimum, and indeed our model is able to eliminate both of those puzzles. As evident from the impulse response diagrams, the SVAR model with Divisia are very successful.

Our results are robust to different numbers of lags and to different measures of variables, such as the consumer price index versus the wholesale price index, different measures of money as the monetary aggregate, and the world price of commodities versus the world price of oil as the world variable. The results also remain robust to different groupings of variables and to different samples or sub-periods

2.4.2 Variance Decomposition

In this section we provide the variance decomposition for the selected models displayed in Table 9.¹³ In models 1 and 2 we compare across the two monetary aggregates, simple-sum M3 and Divisia M3 (DM3), with world oil price as the contemporaneously exogenous world variable. In models 6 and 7 we compare across the same two monetary aggregates, but with the world price of commodities as the contemporaneously exogenous world variable.

¹³ The result for other models are available upon request.

Table 9: Forecast Error Variance Decomposition (FEVD) Analysis							
Forecast Error Decomposition: Contribution of Monetary Policy Shocks to Exchange Rate Variation (in percentages)							
Month	Model 1	Model 2	Model 4	Model 5	Model 6	Model 7	Model 10
1	15.968	5.706	17.312	23.97	21.093	8.025	28.417
2	17.104	5.453	18.458	25.165	22.70	7.754	29.890
3	19.67	7.51	20.891	28.292	25.428	10.102	33.094
10	14.954	6.786	15.665	17.92	21.255	7.967	25.158
11	14.354	6.317	15.05	17.134	20.128	7.471	24.007
12	13.945	5.935	14.621	16.548	18.953	7.091	22.667
22	10.993	4.635	11.379	13.183	14.331	4.875	17.974
23	10.378	4.602	10.713	12.387	13.900	4.667	17.468
24	9.773	4.583	10.073	11.589	13.540	4.471	17.053

In model 1, the interbank interest rate is the monetary policy variable, while DM3 acts as an informational indicator variable, measuring the flow of monetary services in the economy's transmission mechanism. Following the monetary policy shock, inclusion of DM3 helps the interest rate explain about 16% of the exchange rate fluctuation during the 1st month and 19.7% during the 3rd month. Even after 10 months, the policy variable can explain almost 15% of the exchange rate fluctuation. Interestingly, 10% of the exchange rate fluctuation is still explained by the interest rate, 24 months after the monetary policy shock.

Model 2 has world oil price as the exogenous world variable and simple-sum M3 as the monetary aggregate. The monetary policy variable is the interbank rate of interest. Following the monetary

policy shock, inclusion of simple-sum M3 helps the interest rate to explain 5.7% of the exchange rate fluctuation during the 1st month and 7.5% during the 3rd month. After 10 months, the policy variable can explain about 6.8% of the exchange rate fluctuation. About 5% of the exchange rate fluctuation is explained by the interest rate, 24 months after the monetary policy shock. Comparing with the Divisia monetary aggregate result in model 1, we find that the information content of DM3 is substantially higher than that of simple-sum M3.

Model 6 has the world commodity price as the exogenous variable and the DM3 as the monetary aggregate. The monetary policy variable is the interbank rate of interest. Following the monetary policy shock, inclusion of DM3 as an informational variable permits the interest rate to explain 21% of the exchange rate fluctuation during the 1st month and 25.428% during the 3rd month. After 10 months following the shock, the policy variable can explain 21% of the exchange rate fluctuation. Interestingly, 13.5% of the exchange rate fluctuation is still explained by the interest rate after 24 months following the monetary policy shock. The variance decomposition analysis shows that inclusion of the monetary aggregate, especially Divisia money, permits the policy rate to explain high percentages of the exchange rate fluctuation. Use of the world commodity price, instead of the world oil price, permits monetary policy to explain higher percentages of the exchange rate fluctuation, as seen by comparing models 1 and 6.

The world commodity price is the exogenous variable in model 7, while simple-sum M3 is the monetary aggregate. The monetary policy variable is the interbank rate of interest. Inclusion of simple-sum M3 permits the interest rate to explain about 8% of the exchange rate fluctuation during the 1st month and 10% during the 3rd month, following the monetary policy shock. After 10 months, the policy variable can explain 8% of the exchange rate fluctuation. About 5% of the exchange rate fluctuation is explained by the interest rate after 24 months. The variance decomposition analysis

shows that simple-sum M3 is substantially less successful than DM3 in explaining the exchange rate fluctuation.

In model 10 the world commodity price is the exogenous variable, and DM2 is the monetary aggregate. The monetary policy variable is the interbank rate of interest. DM2 acts as an informational variable permitting the interest rate to explain 28% of the exchange rate fluctuation during the 1st month and 33% during the 3rd month, following the monetary policy shock. After 10 months, the policy variable can explain 25% of the exchange rate fluctuation. Even 24 months after the monetary policy shock, 17% of the exchange rate fluctuation is still explained by the interest rate. The performance of the models was evaluated on the basis of (i) how successfully they addressed the prevalent puzzles in the exchange rate literature and (ii) the contribution of the monetary policy shock in explaining the exchange rate variations. The model with Divisia M3 consistently performed better than the model with simple sum M3. Also when we compared among models with the Divisia indexes, i.e. Divisia M2, Divisia M3, and Divisia L1, the model with narrowest Divisia index (Divisia M2) seems to outperform other models.

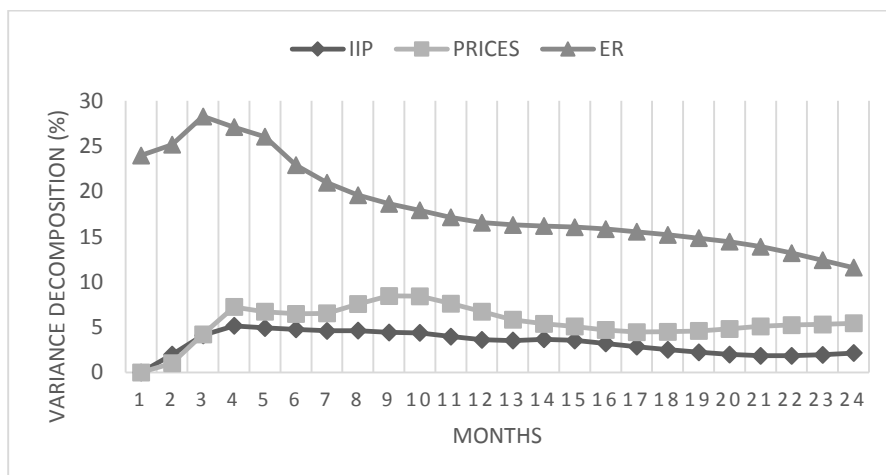
2.4.3 Flip-Flop Analysis

In this section we do a flip-flop analysis. Figure 14 represents the fluctuations in the fundamental variables --- exchange rate, inflation, and economic activity --- being explained by the policy variable. Figure 15 displays how much of each of the fundamental variables can be explained by

movements in the policy variable. We have analyzed the first 10 models. To conserve on journal space, we display the results only with model 5.¹⁴

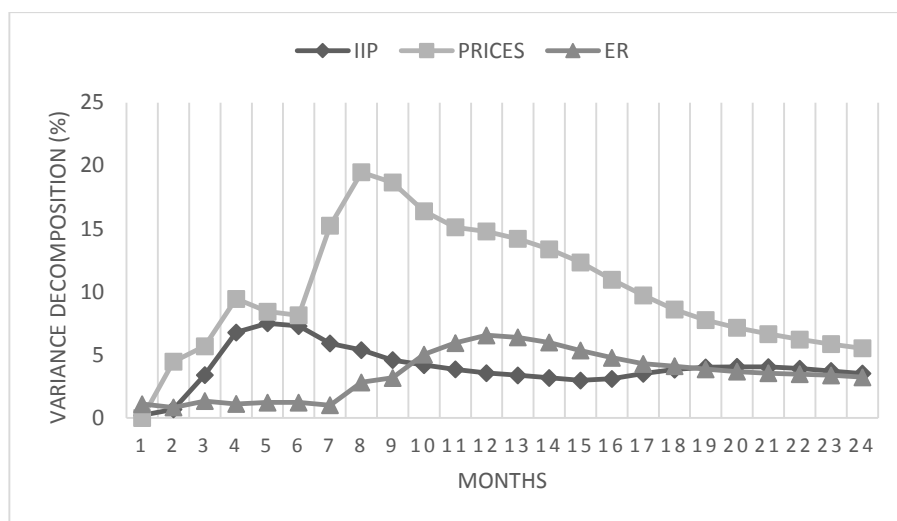
In Figure 14, the monetary policy shock can explain 25-30% of the fluctuation in the exchange rate during the first 6 months, and then 25-15% between the 6th and 18th month. Monetary policy shocks explain 5-10% of the prices fluctuations throughout most of the trajectory. However, the monetary policy shock can explain less than 5% of the fluctuation in real variables, such as industrial production represented by GDP. The weak monetary transmission mechanism might be a consequence of India's underdeveloped financial sector.

Figure 14: Monetary policy explaining fundamental variables



¹⁴ The result for other models are available upon request.

Figure 15: Fundamental variables explaining monetary policy



According to Figure 15, the central bank in India seems to set its monetary policy rule based on inflation-targeting as a primary objective. Close to 20% of the fluctuation in the monetary policy variable is explained by inflation during the 8th month following the shock. For the first 10 months, GDP explains more of the fluctuation in the policy variable than nominal exchange rate (NER) does. But for the next 8 months, NER explains more of that fluctuation. GDP and NER can account for 3%-7% of the fluctuation in the interest rate.

In summary, there is a weak link between the nominal-policy variable and real-economic activity, and the Indian monetary authority had inflation-targeting as one of its primary goals. These results are robust, across different time periods, dissimilar monetary aggregates, and diverse exogenous model specifications.

2.4.4 Forecast Statistics for Exchange Rate

In this section we compare different VAR models in terms of their ability to perform out-of-sample exchange rates forecasts. The purpose of our analysis is to assess the role of money in short and long

horizon forecasting of the exchange rate. A short sample may be insufficient to make a 24-periods ahead forecast. Therefore, the choice of the sample is driven by the availability of Ramachandran, Das, and Bhoi's Indian Divisia data, which start from 1993:04 and end at 2008:06. The criteria used to measure forecast errors are Root Mean Square Error (RMSE) and Theil U statistic. We calculate "out-of-sample" forecasts within the data range by using the Kalman filter to estimate the model up to the starting period of each set of forecasts. Our purpose is not to find the best forecasting model, but to determine how the forecasting performance changes, when we add money to the system and when we use different measures of money. We estimate the model through 2006:6 and do updates for the period 2006:7 to 2008:6 using the Kalman filter for the 24 steps. Forecast performance statistics are compiled over that period.

We begin by computing

$$e_{it} = y_t - \hat{y}_{it}, \quad (2.9)$$

where \hat{y}_{it} is the forecast at step t from the i^{th} call, and y_t is the observed value of the dependent variable. Let N_t be the number of times that a forecast has been computed for horizon t , with $i = 1, 2, \dots, N_t$. Then the Root Mean Square Error of the forecasts is

$$RMSE_t = \sqrt{\frac{\sum_{i=1}^{N_t} e_{it}^2}{N_t}}. \quad (2.10)$$

In contrast, the RMSE of the no-change (martingale) forecasts are

$$RMSE_{NCF_t} = \sqrt{\frac{\sum_{i=1}^{N_t} (y_{it} - y_{i0})^2}{N_t}}, \quad (2.11)$$

where y_{i0} is the “naive” or flat forecast --- the value of the dependent variable at the start period for the i^{th} call.

Theil’s U statistic (Doan (2013)) is

$$U_t = \frac{RMSE_t}{RMSE_{NCF_t}}, \quad (2.12)$$

which is a unit free measurement. A value less than one indicates a good forecasting model.

Table 10 compares the model with simple-sum M3 versus Divisia M3 with 24- step ahead forecasts. The model with Divisia M3 produces lower RMSE and Theil U values than the model with simple-sum M3. The difference between the RMSE and Theil U grows over time, perhaps suggesting that Divisia M3 facilitates longer-horizon forecasting.

Table 10: Forecast Statistics for Exchange rate				
STEP	RMSE (DM3)	RMSE (M3)	Theil U (DM3)	Theil U (M3)
1	0.016817268	0.0168186	0.9407059	0.940740
2	0.027939798	0.0279426	0.9465474	0.946622
3	0.035327661	0.0353301	0.94694318	0.94701555
4	0.04509268	0.045096935	0.97101692	0.97110852
5	0.053015259	0.053020313	0.98133839	0.98143195
6	0.061130186	0.061135251	0.98933159	0.98941357
7	0.07159638	0.071601885	1.00796044	1.00803795

8	0.081620156	0.081625622	1.02052515	1.02059349
9	0.090236999	0.090240718	1.01969010	1.01973213
10	0.101070039	0.101074766	1.03026120	1.03030939
11	0.109619074	0.109625888	1.03736232	1.03742681
12	0.115919549	0.115927138	1.04535736	1.04542579
13	0.122422252	0.122431367	1.05291817	1.05299657
14	0.125861402	0.125869018	1.05283130	1.05289501
15	0.131125827	0.131134336	1.05436936	1.05443778
16	0.135008923	0.135019462	1.05461511	1.05469744
17	0.13596275	0.135975093	1.05532448	1.05542028
18	0.136027792	0.13604202	1.05607557	1.05618603
19	0.134682711	0.134698657	1.05710163	1.05722679
20	0.130837069	0.130854786	1.06003547	1.06017902
21	0.125022931	0.125042025	1.06517634	1.06533902
22	0.118076898	0.118096956	1.07450819	1.07469072
23	0.094336989	0.094357902	1.10405841	1.10430315
24	0.08290196	0.082923123	1.13793843	1.13822892

The results imply the following: the exchange rate forecasting model with money performed better than the model without money, and the exchange rate forecasting model with Divisia money performed better than the model with simple-sum money.

The forecast graphs, figures 16 and 17, are obtained through Gibbs sampling on a Bayesian VAR with a “Minnesota” prior. The sequential likelihood ratio test selects 13 lags for the model for the given period. We hold back a part of the data to use for evaluating forecast performance. The graph forecasts 24 steps ahead with a \pm two standard error band using 2500 draws. The out of the sample simulations accounts for two sources of uncertainty in forecasts: both the uncertainty regarding the coefficients (handled by Gibbs sampling) and the shocks during the forecast period (see Doan (2012)).

Figure 16: Out of sample forecast graph (Model without money and Divisia M3)

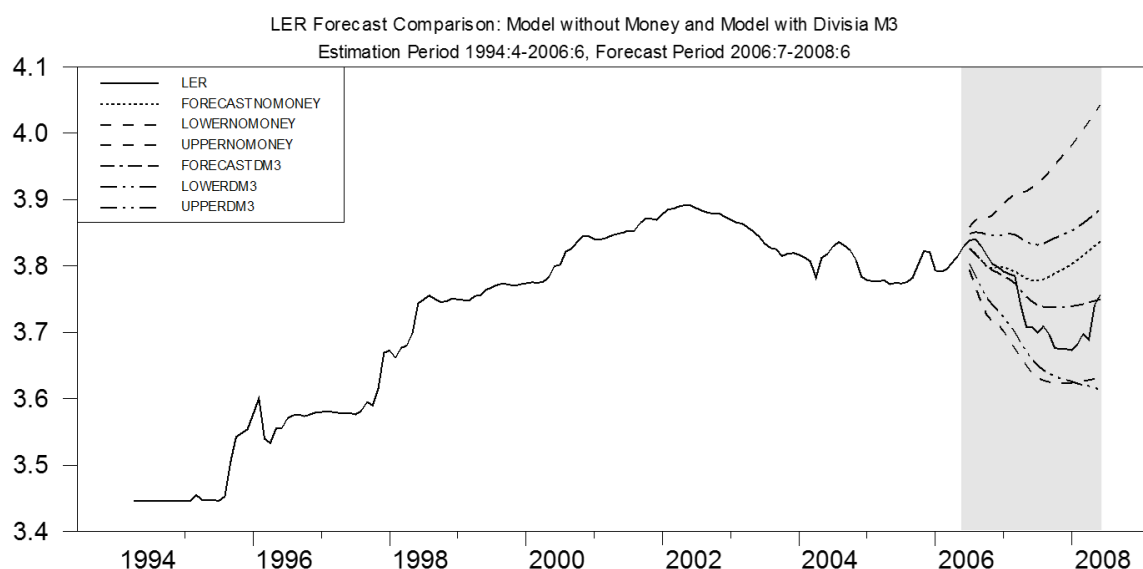


Figure 16 represents the out of sample forecasting graph, and compares the model without money to the model with Divisia M3. The model forecast with Divisia M3 stays closer to the log of the actual exchange rate (LER) value. The model forecast with no money clearly diverges from

actual value over time. The forecast band for the model with Divisia M3 lies within the forecast band for the model with no money, implying that model with Divisia M3 can predict the exchange rate with greater precision.

Figure 17 represents the out of sample forecasting graph for the log of exchange rate and compares the model with simple-sum M3 to the model with the Divisia M3. The model forecast with Divisia M3 remains closer to the actual LER value. The model forecast with simple-sum M3 diverges from the actual value over time. The forecast band for the model with Divisia M3 is narrower than the forecast band with simple-sum M3. This result reflects higher forecast accuracy in models with Divisia money than with simple sum money.

We have evaluated the relative performance of models using the out-of-sample forecasting graphs and the RMSE and Theil U statistic. We conclude that the model with Divisia M3 performs better than with simple-sum M3, which in turn does better than the model with no money. This conclusion applies to forecasting exchange rates both in the short-run and the long-run, and the result is robust to different levels of monetary aggregation.

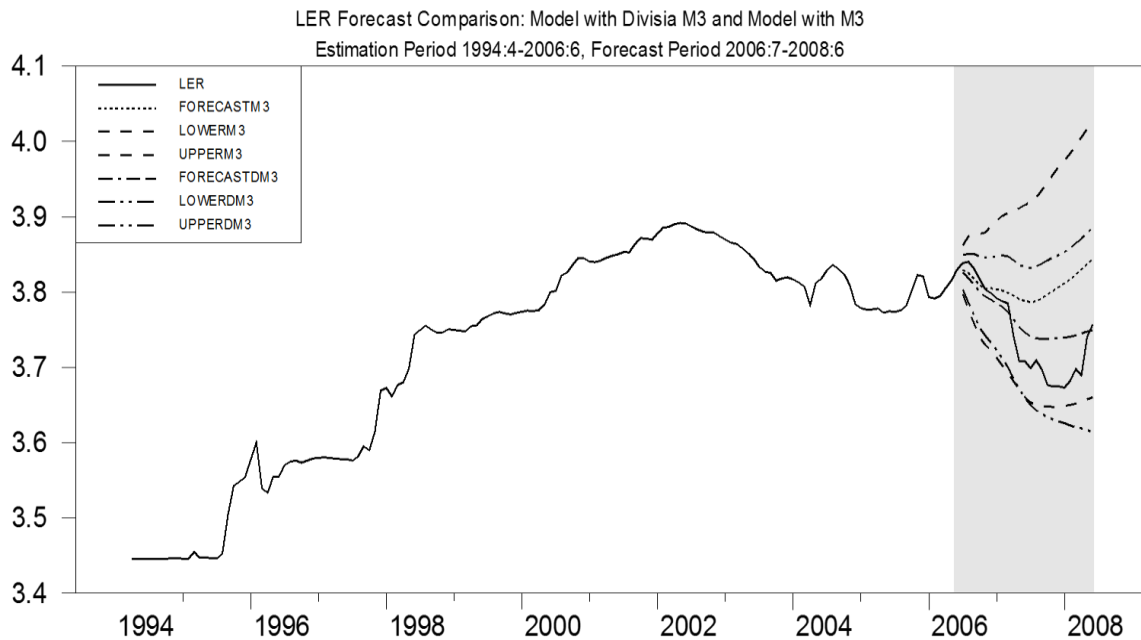


Figure 17: Out of sample forecast graph (Model with M3 and Divisia M3)

2.5 Conclusion

In this paper, we have applied the aggregation theoretic Divisia monetary aggregate in the exchange rate determination for India. We compare across models with and without money.

Our SVAR model was found to be free of the price puzzle and the exchange rate puzzle. We compared the contemporaneous SVAR with the recursive model. In the recursive model, both the price puzzle and the exchange rate puzzle appeared. Some minor evidence of the output-puzzle in the SVAR did appear. For countries like India, with maturing financial markets, financial signals might be transmitted slowly to the real sectors. In that sense, the monetary transmission mechanism might be weak and delayed.

The variance decomposition analysis in our SVAR model provided further insights. We found that introduction of money added valuable information by explaining significantly more of the exchange

rate fluctuations, when compared to the no-money model. In addition, Divisia money's explanatory power was higher than simple-sum money. Our out-of-sample forecasting results were analyzed and compared using the RMSE and Theil U statistics. In general, the inclusion of money lowered the RMSE values, and Divisia money model did better than simple-sum model.

Finally, we did flip-flop analysis, by which we provided a pictorial representation of how much monetary policy in India can explain exchange rate, inflation, and production movements, as well as how much these variables can explain movements in the policy variable. Our results showed that during the estimation period 2000(1)-2008(1), monetary policy is able to explain most of the exchange rate fluctuations, followed by inflation fluctuations, but little of the output movements. Conversely, inflation is able to explain most of the policy-variable changes. This leads us to believe that the central bank of India emphasized inflation-targeting.

We found that models with monetary aggregates perform better than those without money, and that models with the Divisia monetary aggregates outperform those with the simple sum aggregates. This result is consistent with a number of recent papers by Serletis and Rahman (2013), Serletis and Gogas (2014), Serletis and Istiak (2015), and Serletis and Rahman (2015). We conclude that inclusion of Divisia monetary aggregates in an open economy model helps substantially in explaining exchange rate response to central bank interest rate shocks and in resolving the paradoxes that have plagued the literature on exchange rate fluctuations.

Chapter 3: Divisia Monetary Model of Exchange Rate Determination: A Multi-country Analysis

3.1 Introduction

The last decade witnessed monetary aggregates losing its prominence in the macroeconomics literature especially in monetary models of exchange rates. This was largely due to the breakdown of the stability of money demand after the mid-1970s, an era characterized by financial liberalization and financial innovations. Technological developments and financial innovations like the electronic funds transfer, money market accounts, ATMs and the Credit Cards etc. completely changed the dynamics of monetary aggregate variable. As the financial system became more complex with technological advancement and financial innovations (internet banking and mobile banking etc.), the money demand function became even more unstable. It became simply convenient to do away with the monetary aggregates and consider interest rate as the sole monetary policy variable.

However the recent financial crisis of 2007-08 has witnessed series of unconventional monetary policies practiced by major central banks such as large-scale asset purchase, long-maturity lending to banks, cutting deposit rates below zero, purchase of asset backed securities. Naturally such unconventional monetary policy measures have failed to get correctly captured in the key policy rates. In fact it will be misleading to measure the impact of monetary policy and thereby rightly track the monetary policy transmission mechanism with the interest rates alone (when the rates are already stuck near zero). Practical consideration also suggest including money in the central bank's policy rule. If the central bank does not have contemporaneous information on inflation and output, but it does have observation on the money stock, then money may help the central bank infer current values of the variable it cares about directly. See, e.g. Goodfriend (1999), Cochrane (2007), Christiano et al. (2007). Therefore it is important to understand the role of 'money' in exchange rate determination. The way central banks around the world (including Federal Reserve) compute the money supply is through the simple-sum accounting measure. With this approach, it makes no distinction between the 'money-ness' i.e. spending potency of cash versus that of interest bearing time deposit. Second, the conventional monetary measure fails to take into account the contribution to liquidity from assets such as commercial paper or Treasury bills, which are at least somewhat spendable. For example, Fed's broad measure of money supply (M2) grew at 4% to 6% annually during the housing bubble and then 2% in 2010 in the aftermath of the burst. But a measure from the New York-based Center for Financial Stability, Divisia monetary aggregate, capture more kinds of money and using a technically sound computing method found that the money supply (M2) in U.S. grew at 6% to 8% during the bubble and outright shrank to negative growth number following the crisis.

A large literature exists on the empirical and theoretical merits of the Divisia monetary aggregates, Barnett and Serletis (2000), Belongia and Binner (2001), Barnett and Chauvet (2011) and Barnett

(2012). Belongia and Ireland (2015) have tried to acknowledge the role of monetary aggregate especially correctly measured aggregates like Divisia in explaining aggregate fluctuations in the macroeconomic variables. This seems all the more relevant after the substantial change in the monetary policy stance following the 2008 crisis. Of particular relevance is Barnett and Kwag (2005), who find that introducing Divisia aggregates into money market equilibrium condition helps improve the forecasting performance of the monetary models of exchange rate. A source of much of that literature is the online library maintained by the Center for Financial Stability in New York City. The natural question that arises from the discussion so far is twofold and requires careful consideration. First, why it is necessary to bring back ‘money’ when the role of money has been increasingly deemphasized in the literature, especially in the macroeconomic models that analyze policy? Let us consider for illustrative purpose, that there is an increase in the money demand caused by investment portfolio shifts of the private sector. Also the central bank desires to maintain a certain stock of money that supports an inflation target. Any model that explicitly separates the central bank’s behavior from the private sector activity can aid the policymaker decide how much the money supply needs to be adjusted accordingly to achieve the inflation target. Therefore in order to correctly estimate the impact of monetary policy (through the rate cuts), we need to sort out the central bank’s behavior from that of many other market participants (producers, consumers, financial market participants). This sorting-out process helps achieve correct identification of monetary policy and calls for introduction of monetary aggregate back in macroeconomic models that analyze monetary policy.

The follow up question to this argument, why it is needful to correctly ‘count’ money? Let us go back to the early 1980s and focus on the episode of disinflation and financial deregulation. During this period, simple sum series overstated the money growth by failing to internalize the portfolio

shifts out of the traditional non-interest bearing monetary assets into newly created less liquid, interest-earning account such as the money market mutual fund. However the Divisia measures have provided a stronger and more accurate signal of monetary tightness during the same period. Also the Divisia M2 has grown at a rate that consistently exceeded the growth rate of simple sum M2, especially in the periods of falling interest rates of 1990-91, 2001 and 2007-09 recession, see Belongia and Ireland (2015). Friedman's prediction of the economy returning to higher inflation during the 1984-85 was based on the steady growth of the simple sum monetary aggregate. Barnett (2012) mentioned that Friedman might have reached a different conclusion, had he monitored data on Divisia aggregate instead.

Therefore the usage of incorrect measures of monetary accounting can prevent the central bank to rightly track the money demand behavior of the private agent. This is crucial to monetary policy identification and measuring the impact of monetary policy on macroeconomic variables. The miscounting problem can aggravate further in a period of unconventional monetary policies such as large-scale asset purchase, long-maturity lending to banks, cutting deposit rates below zero, purchase of asset backed securities etc. and therefore the need to use the right monetary indicator is even more pressing.

Hendrickson (2014) points out that 'Money' typically has one of the three roles in the empirical analysis. First, the analysis of money demand is important because the existence of stable money demand function is necessary for money to have a predictable influence on other economic variable. Second, the role of money in forecasting inflation and/or nominal income i.e. any type of quantity-theoretic analysis implies that money should predict movements in the price level and nominal income. Third, studies explaining movement in the output gap i.e. the short-run non-neutrality of

money has recently been analyzed in the context of an IS equation to assess whether the real money balances can explain movements in the output gap.

However the role of money and especially the micro-foundation theoretic monetary aggregate like Divisia monetary index hasn't been comprehensively studied in the open-economy macroeconomic setting. For example what is the role of a stable money demand and its predictable influence on variables like exchange rate? What role money plays in forecasting and determination of exchange rate? Yes, studies have tried to analyze the short run non-neutrality of money in terms of being able to explain movements in output gap. But seldom attempts have been made in explaining the gap in the nominal/real exchange rate from its target or desired level. These questions become particularly relevant for small, open and resource-reliant economies.

In fact Divisia money provides an index of 'monetary services' which captures the traditional transaction motive for holding money i.e. money demand. However if our claim that the Divisia aggregate is an accurate measure of the money demand behavior of the private agents is correct. Also if the money demand is expected to influence the exchange rate or the determinants of exchange rate, then the Divisia measure should be a good predictor of the open macroeconomic variables that determine the exchange rate. Therefore a modified Wald test criterion suggested by Toda-Yamamoto is taken up in evaluating the information content of the Divisia monetary aggregate along with the alternative monetary policy indicators. The finding in this paper challenges the traditional view that short-term/ immediate rate of interest have better predictive power on the exchange rate than the alternative monetary indicators.

Finally, we use the structural vector auto regression (SVAR) similar to Kim and Roubini (2000) to gauge the effects of central bank's monetary policy in the years leading up to and immediately following the financial crisis of 2007-2008. To anticipate the results in the paper, our identification

scheme appears to be successful in identifying monetary policy shocks and solving the major empirical puzzles about the effects of monetary policy shocks for Poland, India and U.K. In this paper we estimate a range of identified VAR models of monetary policy based on different kinds of monetary aggregates at varying level of aggregation. Comparing the results across the models, we find that a policy shock that generates the same initial change in the immediate rate of interest yields significantly different output effects and price effects, depending on what kind of ‘money’ enters the model. Also the kind of money that enters into the model determines distinct response of exchange rate to a policy disturbance. The results suggest that the short-term/immediate rate of interest is not sufficient to identify the quantitative effects of monetary policy in empirical models. We find that by making use of valuable new data on the Divisia aggregates provided by the Center for Financial Stability, New York and described by Barnett et al. (2013), we obtain puzzle-free results at the different level of Divisia aggregation.

The paper is organized as follows. We have 3 subsections, Subsection 3.2 illustrate the Toda Yamamoto Granger causality analysis. In section 3.3, we discuss the SVAR estimation, with model and identification. The empirical results are presented in section 3.4 and finally we conclude in section 3.5.

3.2 Toda-Yamamoto Granger Causality

Sims (1980) and Litterman and Weiss (1985) found that interest rate tend to absorb the predictive power of money. Money might have less information content and therefore less predictive power on output poses serious challenge to the traditional view “money leads income” argument for monetary policy effectiveness. Bernanke and Blinder (B&B, 1992) have tried to address the question about the predictive power of money by using the marginal significance levels of the monetary indicators (like the federal fund rate, three-month Treasury bill rate and ten-year government bond rate) for

forecasting alternative measures of economic activity (industrial production, capacity utilization, employment, unemployment rate, etc.) and by using variance decomposition of the forecasted variables. They conclude that the fed fund rate is an excellent measure of the stance of monetary policy. The authors successfully find evidence that short-run variation in the fed-fund rate are mostly attributable to Federal Reserve policy decision and not to the fluctuations in the demand for reserves. Following the results of B&B, Belongia and Ireland (B&I, 2015) have tried to reassess similar question. B&I attempt to reexamine the relative information content of money and interest rate in explaining variations in the real activity. Notice that B&I use exactly the same nine measures of real economic activity as B&B. B&I try to find the effects of measurement on the inferences about money's effect on the economic activity. They limit their work to estimations with simple sum measures of M1 and M2 and fed fund rate. Additionally they use the Divisia measures of M1, M2 and MZM (M2, less small time deposits, plus the institution-only Money market mutual funds). B&I find that Divisia measures of money are most closely linked to the movements in the real economic activity, compared not only to the corresponding simple sum measures but also to the federal fund rate which is significant in only four out of nine cases. Their message is-"the loss of explanatory power for the monetary aggregates on the economic activity can be traced to the continued use of Fed's flawed simple sum aggregation method".

However the role of money and especially superior form of monetary aggregate like Divisia hasn't been comprehensively studied in the open-economy macroeconomic setting. In the current framework, our research question is directed towards the effects of correctly measured money and their effect on open-economy variables that have got significant influence on the exchange rate determination. Against this backdrop, various models of exchange rate determination are carefully

examined in determining our choice of open-economy variables that can directly or indirectly influence the exchange rate, see Dua and Ranjan (2011).

The variables that are chosen are Balance of Goods, Balance of Services, Current Account Balance, Capital Account Balance, Gross Domestic Product, Inflation, 3-month forward premium, Net Trade in Goods, Divisia and Simple sum measures of money supply, Short term or immediate rate of interest. We present a thorough analysis of the marginal significance levels of the monetary indicators on the variables that directly or indirectly influence exchange rate movements. The choice of the countries are subject to the Divisia data availability i.e. Poland, India and U.K. All series are seasonally adjusted and obtained from O.E.C.D. database, FRED, St. Louis, Bank of Poland, and Bank of England. The series are in quarterly frequency to accommodate gross domestic product, which is one of the important determinants of exchange rate and published in quarterly frequency. For Poland the sample period: 2000Q1 2015Q4, for India the sample period: 1996Q1 2008Q1, for United Kingdom the sample period: 1999Q1 2014Q1.

During our analysis, we follow the Toda and Yamamoto (T&Y, 1995) procedure to test for Granger Causality criterion. The T&Y procedure proposes a simple way to overcome the problems in hypothesis testing that are encountered when the VAR processes may have unit roots. T-Y method is applicable whether the VAR's may be stationary (around a deterministic trend), integrated of an arbitrary order, or cointegrated of an arbitrary order. Consequently, one can test linear or nonlinear restrictions on the coefficients by estimating a level VAR and applying the Wald criterion, without bothering about the integration and cointegration properties of the time series data in hand.

The table shows the modified Wald test statistics that will be asymptotically chi-squared distributed with p degrees of freedom; where p^{15} represents the appropriate maximum lag length of the variable. The choice of p is based on the sequential modified LR test statistic (LR), Final prediction error (FPE), Akaike information criterion (AIC), Schwarz information criterion (SIC), Hannan-Quinn criterion (HQ). While determining the p , it is ensured that the autocorrelation issues are resolved. The rejection of the null hypothesis implies a rejection of Granger non-causality. That is, a rejection of the null supports the alternative hypothesis i.e. the column variable Granger Cause the row variable. The column variables in the table represent alternative monetary indicators i.e. simple sum monetary aggregate, Divisia monetary aggregate and immediate interest rate. The row variables represent alternative determinants of exchange rate. The performance of the monetary indicators are evaluated not only in terms of the absolute value of the Wald test statistic, but also the relative comparison is made between the alternative monetary indicators. The monetary indicator's predictive contribution is evaluated in terms of statistical significance at better than 1%, 5% and 10% level for the variables that determine exchange rate, denoted by *, ** and *** respectively.

Table 11.A, 11.B and 11.C shows that for Poland, according to the Granger Causality criterion, Divisia monetary aggregates, Divisia M2 and Divisia M3 are by far the best predictor variables among the other monetary indicators like immediate rate of interest, simple sum M1, simple sum M2, simple sum M3 and Divisia aggregate at lower levels of aggregation i.e. Divisia M1. In fact, Divisia M3 is superior to any other monetary indicators in terms of predicting 8 out of 9 determinants

¹⁵ For U.K., India and Poland, the appropriate maximum lag length are 5, 4 and 5 respectively.

of exchange rate. Divisia M2 also perform fairly well in terms of predicting 7 out of 9 determinants of exchange rate. Even in the presence of the alternative monetary indicators like simple sum M3 and immediate rate of interest, the Divisia M3's predictive contribution is statistically significant at better than the 5-percent level for every variable except Balance of Services. No other money or interest rate variable is significant at this level more than thrice.

Table 12 A shows that according to the Granger-causality criterion, both Divisia and simple sum monetary aggregate at M3 level of aggregation are relatively better predictive variable among the monetary indicators for India. Even in the presence of the immediate rate of interest, Divisia M3 and simple sum M3's predictive contribution is statistically significant for the Gross Domestic Product at 1-percent level of significance. In fact, simple sum M3 predictive contribution is statistically significant for Balance of services at 5-percent level of significance. Surprisingly rate of interest has virtually no predictive power at all for India.

<p>Table 11: Poland</p> <p>Marginal significance levels of the monetary indicators for forecasting alternative determinants of the exchange rate</p>									
	<u>Table11A</u>			<u>Table11B</u>			<u>Table11C</u>		
Variables	R	Simple Sum M3	Divisia M3	R	Simple Sum M2	Divisia M2	R	Simple Sum M1	Divisia M1
Balance of Goods	0.4969	0.1904	0.0020*	0.6331	0.0073*	0.0000*	0.0977***	0.5646	0.2763
Balance of Services	0.9325	0.6799	0.3862	0.8892	0.535	0.3355	0.4355	0.0834***	0.1701
Capital Account Balance	0.3275	0.0058*	0.0012*	0.5914	0.0044*	0.0024*	0.5099	0.1553	0.1057
Current Account Balance	0.8055	0.2262	0.0057*	0.9276	0.0207**	0.0001*	0.6915	0.0558***	0.0156**
Exchange Rate	0.0261**	0.3028	0.0220**	0.0567* **	0.7046	0.0357**	0.0679***	0.6044	0.9867
Gross Domestic Product	0.9068	0.0996***	0.0359**	0.9209	0.1567	0.0605***	0.7353	0.908	0.8807
Net Trade in Goods	0.1719	0.0339**	0.0000*	0.4487	0.1587	0.0001*	0.0312**	0.9243	0.256
Inflation	0.223	0.4303	0.0584***	0.2507	0.9593	0.5318	0.742	0.214	0.1356

Table 12: India						
Marginal significance levels of the monetary indicators for forecasting alternative determinants of the exchange rate						
	Table 12A		Table 12B		Table 12C	
Variables	R	Simple	Divisi	R	Divisia	R
Balance of Goods	0.99	Sum M3 0.53	M3 0.43	L1 0.31	M2 0.10	M3 0.30
Balance of Services	0.89	0.04**	0.41	0.73	0.09***	0.75
Capital Account	0.83	0.70	0.81	0.97	0.06***	0.85
Exchange Rate	0.87	0.82	0.71	0.86	0.16	0.14
Gross Domestic	0.56	0.00*	0.01*	0.97	0.00*	0.50
Net Trade in Goods	0.90	0.66	0.11	0.47	0.00*	0.68
Inflation	0.79	0.55	0.84	0.16	0.78	0.62
						0.77
						0.08***
						0.01*
						0.25
						0.35
						0.74
						0.00*
						0.82
						0.68
						0.16
						0.93
						0.00*
						0.46
						0.79
						0.62
						0.77

Table 13: UK									
Marginal significance levels of the monetary indicators for forecasting alternative determinants of the exchange rate									
	Table 13A			Table 13B			Table 13C		
Variables	R	Simple Sum M1	Divisia 1	R	Simple Sum M3	Divisia 1	R	Simple Sum M1	Divisia 2
Balance of Goods	0.0849***	0.0222**	0.4564	0.5641	0.9676	0.3005	0.0007*	0.0002*	0.0373**
Balance of Services	0.0012*	0.0190**	0.5626	0.0000*	0.5799	0.4583	0.0000*	0.3708	0.8976
Current Account Balance	0.6446	0.9631	0.9974	0.2117	0.8794	0.6363	0.609	0.5856	0.3056
Capital Account Balance	0.6862	0.3236	0.4361	0.4627	0.2919	0.7256	0.7054	0.3234	0.9082
Net Trade in Goods	0.5762	0.3155	0.2413	0.3237	0.5657	0.0735***	0.4131	0.0747***	0.8539
Gross Domestic Product	0.5719	0.0553***	0.0719***	0.8564	0.4377	0.5316	0.2725	0.0031*	0.0105**
Inflation	0.0029*	0.0027*	0.0057*	0.0437**	0.0945***	0.1323	0.0065*	0.0099*	0.0018*
Exchange Rate	0.8959	0.3487	0.0983***	0.8333	0.5508	0.0222**	0.4568	0.0048*	0.0495**
3-Month Forward	0.2735	0.1184	0.0882***	0.0495**	0.8334	0.0712***	0.0639***	0.0425**	0.2775

Due to the unavailability of institutionalized monetary data on Divisia and their simple sum counterparts at similar levels of aggregation for India, we evaluate the relative performance of the Divisia monetary aggregate and simple sum money with the immediate rate of interest. Table 12B, 12C and 12D compares the performance of Divisia L1, Divisia M2 and Divisia M3 with the immediate rate of interest, as the predictive variable for the determinants of the exchange rate. Similarly Table 12E compares the performance of simple sum M1 with the immediate rate of interest. Table 12B, 12C and 12D show that the Divisia monetary aggregate at different levels of aggregation i.e. Divisia L1, Divisia M2, Divisia M3 are superior to the immediate rate of interest for India. The Divisia aggregates' predictive contribution is statistically significant at better than 10-percent level for at least three determinants of exchange rate. The Gross Domestic Product, Net Trade in Goods, Balance of Services and Current Account Balance are consistently predicted by the Divisia monetary aggregate at different levels of aggregation. The immediate rate of interest has virtually no predictive power on the determinants of the exchange rate.

Table 12E shows that simple sum measures at M1 level of aggregation is also superior to the immediate rate of interest for India. The Gross Domestic Product, Net Trade in Goods, Balance of Services and Inflation are some of the determinants of exchange rate that are being predicted by the simple sum measures. Overall for India, we observe that in the presence of the simple sum and Divisia monetary aggregates at different levels of aggregation, the immediate rate of interest's predictive contribution towards the determinants of the exchange rate is discouraging.

Table 13A, 13B and 13C shows the marginal significance levels for the hypothesis that whether simple sum, Divisia monetary aggregate or immediate interest rate can be excluded or not in predicting the determinants of exchange rate for U.K. The row variables are the direct or indirect determinants of the exchange rate for U.K. and the column variables are the monetary indicators

comprising combination of simple sum and Divisia measures at different levels of aggregation along with immediate rate of interest. Notice that we consider an additional determinant of exchange rate i.e. 3-month forward premium for U.K.

The results for U.K. shows that, according to the Granger-causality criterion all the three measures of monetary indicators i.e. Divisia 1 and Divisia 2, simple sum M1 and M3, immediate rate of interest perform well in terms of predictive variables for the determinants of the exchange rate. Almost all of the monetary indicators is significant at this level at least thrice. Inflation is one unique variable that gets significantly predicted almost each time by all the three measures of monetary indicators. Divisia measures does relatively well in predicting Exchange Rate. Also the Gross Domestic Product is consistently predicted by both the simple sum and Divisia measures. The immediate rate of interest consistently predict the Balance of Goods and Balance of Services.

We have been using the Granger-causality criterion so far to assess the predictive powers of the monetary indicators. There is an excellent point that was raised by B&B in regards to some drawback of using the current approach. The problem arises because the monetary indicator variables are not orthogonal. Sims (1980), Litterman and Weiss (1985) have focused on a different way of evaluating the predictive power i.e. constructed from a VAR with the orthogonalized residuals: the percentage of the variance of the forecasted variable attributable to alternative monetary indicators. However B&B have rightly pointed out that even this particular metric has its own serious drawback, including dependence on the ordering of the forecasted variable. Therefore rather than carry on a debate over which metric measure is superior, let us say that the Granger-causality criterion can still convey valuable information in determining the predictive power of the monetary indicators.

3.3 Estimation

3.3.1 Model

The system of equation representing dynamic structural models can be collected and written in the vector form as

$$B_0 y_t = k + B_1 y_{t-1} + B_2 y_{t-2} + \dots + B_p y_{t-p} + u_t \quad (3.1)$$

Where y_t is an $n \times 1$ data vector, k is an $n \times 1$ data vector of constants and u_t is an $n \times 1$ structural disturbances vector. u_t is serially and mutually uncorrelated. p denotes the number of lags.

$$B_0 = \begin{bmatrix} 1 & -B_{12}^{(0)} & . & . & . & . & -B_{1n}^{(0)} \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ -B_{n1}^{(0)} & -B_{n2}^{(0)} & . & . & . & . & 1 \end{bmatrix} \quad (3.2)$$

B_s is a $(n \times n)$ matrix whose row i , column j element is given by $B_{ij}^{(s)}$ for $s=1, 2, \dots, p$.

If each side of [3.1] is pre-multiplied by B_0^{-1} , the result is

$$y_t = c + \phi_1 y_{t-1} + \phi_2 y_{t-2} + \dots + \phi_p y_{t-p} + \epsilon_t \quad (3.3)$$

$$\text{Where, } c = B_0^{-1} k \quad (3.4)$$

$$\phi_s = B_0^{-1} B_s \quad ; \quad \text{for } s = 1, 2, 3, \dots, p \quad (3.5)$$

$$\epsilon_t = B_0^{-1} u_t \quad (3.6)$$

Thus VAR can be viewed as the reduced form of a general dynamic structural model. The structural disturbance u_t and reduced form residuals ϵ_t are related by

$$u_t = B_0 \epsilon_t \quad (3.7)$$

To estimate the parameters from the structural form equations requires that the model be either exactly identified or over-identified. A necessary condition for exact identification is that there

should be same number of parameters in B_0 and D (covariance matrix of the structural form, $E u_t u_t' = D$) as there are in, Ω the covariance matrix from the reduced form, ϵ_t . In other words, it must be possible to recover the structural parameters from the reduced form model, which is known as the order condition. In addition the model should be able to satisfy the rank condition that is more difficult to verify. One of the older but still popular way of doing that is the Cholesky decomposition of reduced form innovations as suggested by Sims (1980). This imposes a recursive structure to identify the model. There are other methods like structural VAR which can be non-recursive with restrictions imposed on instantaneous relations between the variables coming from theory (see Bernanke, 1986 for example). Letting Ω denote the variance-covariance matrix of ϵ_t , implies

$$\Omega = E(\epsilon_t \epsilon_t') = B_0^{-1} E(u_t u_t') (B_0^{-1})' = B_0^{-1} D (B_0^{-1})' \quad (3.8)$$

Since Ω symmetric, it has $n(n+1)/2$ parameters. It is standard in SVAR literature to have D as the diagonal matrix which requires n parameters. Hence B_0 can have no more than $n(n-1)/2$ restrictions for exact identification. B_0 is a triangular matrix for the VAR with Cholesky decomposition of the innovations which makes the economic interpretation of the model difficult.

For an exactly identified model, a simple two-step maximum likelihood estimation (MLE) procedure can be employed, assuming the structural errors are jointly normal. This is the full information maximum likelihood (FIML) estimator for the SVAR model. First, Ω is estimated as,

$$\hat{\Omega} = (1/T) \sum_{t=1}^T \hat{\epsilon}_t \hat{\epsilon}_t' \quad (3.9)$$

Estimates of B_0 and D are then obtained by maximizing the log likelihood for the system conditioned on $\hat{\Omega}$. When the model is over-identified, however, the two-step procedure is not the FIML estimator for the SVAR model. The estimates are consistent but not efficient, since they do not take the over-identification restrictions into account when estimating the reduced form. For an over-identified system, we estimate the VAR model without additional restrictions and the VAR model with

additional restrictions to obtain ‘unrestricted’ and ‘restricted’ variance-covariance matrix, respectively, by maximizing the likelihood function. The difference in determinants of the restricted and unrestricted variance-covariance matrix will be distributed χ^2 with degrees of freedom equal to number of additional restrictions exceeding a just identified system. The χ^2 test statistic is used to test the restricted system.

Ideally, the restrictions imposed to identify a SVAR model would result from a fully specified macroeconomic model. In practice, however, this is rarely done. Instead, the more common approach is to impose a set of identification restrictions that are broadly consistent with the economic theories and provide sensible outcomes. Generally, the metric used is whether the behavior of the dynamic responses of the model accords with the economic theories. Given a set of variables of interest and criteria for model selection, identification restrictions can be imposed in a number of different ways. Most commonly, these involve restrictions on B_0 (the contemporaneous relationships between the variables in the system), B_0^{-1} or the long run restrictions.

3.3.2 Identification

We use a 7-variable VAR including the world oil price index (oilp), the federal fund rate (rfed), the index of industrial production (iip), the level of inflation in the domestic small open economy (π), a domestic monetary aggregate (MD), nominal short-term domestic interest rate (rdom) producing the monetary policy shocks (MP), and the nominal exchange rate in domestic currency per US dollar (ER). Our identification scheme based on equation (3.10) is given below.

$$\begin{pmatrix} u_t^{oil} \\ u_t^{rfed} \\ u_t^{iip} \\ u_t^\pi \\ u_t^{MD} \\ u_t^{MP} \\ u_t^{ER} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ b_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ b_{31} & b_{32} & 1 & 0 & 0 & 0 & 0 \\ b_{41} & 0 & b_{43} & 1 & 0 & 0 & 0 \\ 0 & b_{52} & b_{53} & b_{54} & 1 & b_{56} & b_{57} \\ b_{61} & 0 & 0 & 0 & b_{65} & 1 & b_{67} \\ b_{71} & b_{72} & b_{73} & b_{74} & b_{75} & b_{76} & 1 \end{pmatrix} \begin{pmatrix} \epsilon_t^{oil} \\ \epsilon_t^{rfed} \\ \epsilon_t^{iip} \\ \epsilon_t^\pi \\ \epsilon_t^{MD} \\ \epsilon_t^{MP} \\ \epsilon_t^{ER} \end{pmatrix} \quad (3.10)$$

u is the vector of structural innovations and ϵ is the vector of errors from the reduced form equations where the vector is given by (world price of oil, Fed funds rate shocks, iip shocks, inflation shocks, money demand shocks, monetary policy shocks, and exchange rate shocks). This is very similar to K&R but modified to fit the Indian, Polish and U.K. economy better and render rigorous comparisons of different monetary aggregates. Generally, restrictions on B_0 are motivated in the following way. As in Kim and Roubini (2000), we have a contemporaneously exogenous world shock variable, alternatively captured using the world oil price index. Although none of the domestic variables can affect the world variables contemporaneously, they can do so over the time. Similarly, the federal funds rate in the U.S. is only affected by the world event shocks. No domestic events have enough impact to influence the policy variables of the largest economy in the world. As in Kim and Roubini (2000), it is necessary to include these two variables to isolate and control the exogenous component of monetary policy shocks.

A further behavioral restriction often imposed is that certain variables respond slowly to movements in financial and policy variables. So, for example, output and prices do not respond contemporaneously to changes in domestic monetary policy variables and exchange rates. Real activity, like industrial production, responds to domestic price and financial signals with a lag, as a result of high adjustment costs to production. However, industrial production of a small, open,

economy is deeply impacted by world or outside shocks. Inflation and industrial production are affected by the world shock. People's willingness to hold cash given by the money demand function usually depends on real income and the domestic interest rate. To explore how different monetary aggregates compare in identifying the monetary policy for a small open economy and how they contribute to explaining the exchange rate movements, we assume that the money demand function also depends on the foreign (US) interest rate and the prevailing exchange rates. The monetary policy equation is the monetary authority's reaction function, which sets the interest rate after observing the current value of money supply, the interest rate, and the exchange rate.

The data are in monthly frequency with the estimation period January 2000- January 2008, January 2001-November 2014, December 2001-June 2015, January 2000-May 2015 for India, Poland and U.K. respectively. The index of production of total industry (seasonally adjusted) for UK, Poland and India are obtained from Production and Sales (MEI), OECD database. The consumer price index (all items, seasonally adjusted) for UK, Poland, Israel and India are obtained from Consumer Prices, OECD database. The interest rate that we use immediate interest rate/call money/interbank rate (percent, per annum) for UK, Poland, Israel and India are obtained from Monetary and Financial Statistics (MEI), OECD database. The simple-sum monetary aggregates M1, M3 are the seasonally adjusted narrow and broad money indices respectively for UK, Poland and India. The values of nominal exchange rate (National currency per USD, monthly average) for UK, Poland and India are obtained from Monetary and Financial Statistics, (MEI), OECD database. The monthly crude oil price (per barrel) is obtained from Index Mundi.

The Divisia data that includes the monthly index of monetary financial institutions, sterling Divisia for U.K. is obtained from the Bank of England database. The Divisia M1, Divisia M2 and Divisia M3 (corresponding to their simple-sum counterpart M1, M2 and M3 respectively) are obtained from

the National Bank of Poland database. Divisia monetary aggregate (DM2), (DM3), (DL1) for India, are obtained from Ramachandran, Das and Bhoi, 2010. The estimation period for India is constrained by the availability of a shorter sample of Divisia data from January 2000-January 2008 (see Ramachandran et al.). The Center for Financial Stability, New York, maintains the International Advances in Monetary and Financial Measurement, which has links to the Divisia data for UK, Poland and India. All the series are seasonally adjusted by the official sources except the Indian Divisia, world oil prices which are seasonally adjusted using frequency domain deseasonalization in RATS (see Doan 2013). All variables are in logarithms except the interest rates. Inflation (π) is calculated as the annual change in log of consumer prices. Monthly VAR is estimated using 6 lags for India, and 13 lags for UK and Poland. The lags are selected by sequential likelihood ratio test in RATS (see Doan 2013). The results from sequential likelihood ratio test is presented in table A in the appendix.

3.4 Empirical Results

3.4.1 Impulse Response Analysis

We briefly define the four puzzles that have been widely prevalent in the exchange rate literature. The theory predicts that an increase in the domestic interest rates should lead to an impact appreciation of the exchange rate (exchange rate overshooting) and thereafter depreciation of the currency in line with the uncovered interest parity. Higher return on investments from the increase in domestic interest rates would lead to a higher demand for domestic currency and hence appreciating of the domestic currency relative to the foreign currency. The *exchange rate puzzle* occurs when a restrictive domestic monetary policy leads to an impact depreciation of domestic currency. Alternatively, if the domestic currency appreciates and it does so for a prolonged period of time, violating the uncovered interest parity condition. That phenomenon is known as the *forward*

discount bias puzzle or delayed overshooting. The *liquidity puzzle* results, when a money market shock is associated with increases in the interest rate. This phenomenon reflects the absence of the liquidity effect, defined by negative correlation between monetary aggregates and interest rates. Finally, the *price puzzle* is a phenomenon by which a contractionary monetary policy shock, identified with an increase in interest rates, leads to a persistent rise in price level.

We evaluate the SVAR model in terms of the four prevalent puzzles. Most of the puzzles are eliminated for all the three countries and the results are robust to use of different samples and different monetary aggregates etc. This establishes the correct identification of monetary policies for India, Poland and the U.K. As is shown in our previous work (Barnett et al, 2016), it is imperative to separate the private agent's behavior (money demand) from the central bank's policy (money supply) before assessing the effects of monetary policy on the economy. This calls for the inclusion of money in the models of exchange rates to capture the money demand. Moreover, Divisia index can weigh the different monetary components in a way that properly summarizes the services of the quantities of money.

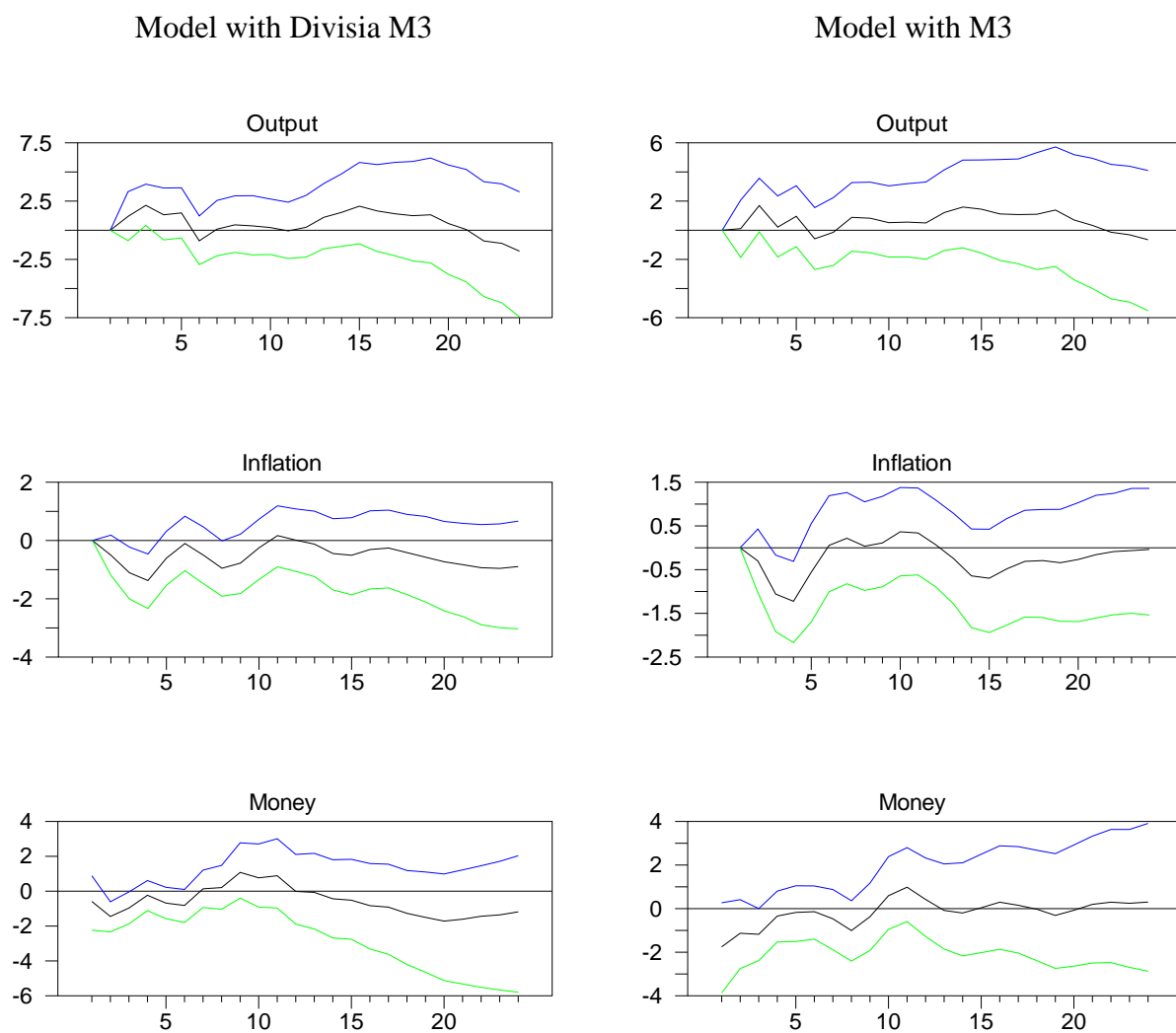
In this section we offer a detailed impulse response analysis comparing the performance of models with Divisia money vis-à-vis models with simple sum money. Also the correct identification of monetary policies using the Divisia money does put forth important insights on monetary transmission mechanisms for these economies, an area warranting detailed work in the future. The statistical significance of impulse responses are examined using the Bayesian Monte Carlo integration in RATS. Random Walk Metropolis Hastings method is used to draw 10000 replications for the over-identified SVAR model. The 0.16 and 0.84 fractiles corresponds to the upper and lower dashed lines of the probability bands (see Doan, 2013).

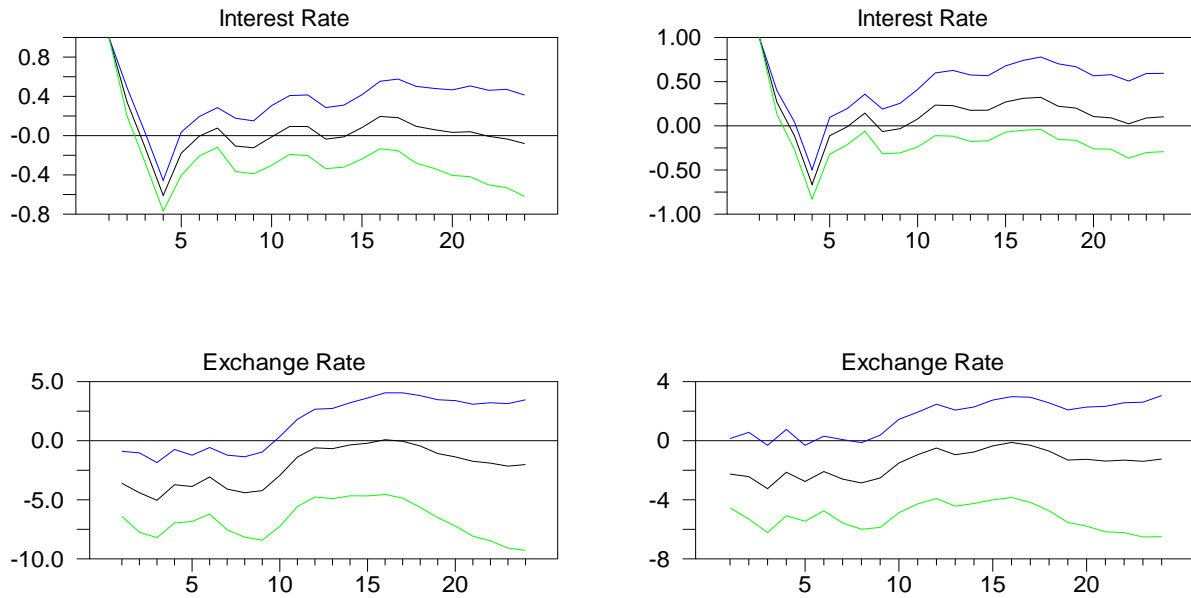
India: Figure 17 compares the impulse response graphs of the SVAR model with simple-sum M3 (left panel) and Divisia M3 (right panel) for India. With a contractionary monetary policy, exchange rate appreciates on impact and depreciates thereafter in both the models. A percentage point increase in interest rate causes approximately 4% appreciation of rupee vis-à-vis US dollar for models with Divisia as opposed to a 2% impact appreciation of the exchange rate in models with simple sum money as given by the point estimates. However, the response of exchange rate (impact appreciation and depreciation afterwards) is significant in the left panel compared to the right panel. Therefore the model with Divisia money is able to capture greater impact of the exchange rate overshooting to monetary policy shock compared to the model that take up simple sum M3.

From the Figure 17, we see that a percentage rise in interest rate causes money demand to fall for few months in both the model but impulse responses only become significant in the left panel. After the monetary policy shock inflation falls by approximately 3% in the left panel compared to 1.2% in the right panel. So we get responses of exchange rate, money demand and prices as expected by theory, that is, our model is able to generate puzzle free results identifying the Indian monetary policy correctly. We observe the liquidity effect, price effect and exchange rate overshooting are more pronounced (significant) for the model with Divisia M3 as compared to the simple sum M3. Therefore we can conclude that for the Indian economy, the monetary transmission mechanism is captured more efficiently when we include Divisia money in the model instead of simple sum counterpart. Also notice that the confidence bands are in general narrower for the models with Divisia aggregate, indicating estimation with greater precision. Finally, monetary policy shock seems to have negligible impact on industrial production. Both the models show insignificant response of real activity to a monetary policy shock. Supply side bottlenecks, lagging manufacturing sector and underdeveloped financial markets could be possible reason behind this.

Figure 18: **Impulse Responses to Monetary Policy Shock for India**

(Estimation period: Jan 2000- Jan 2008, Lags=6)





United Kingdom: Figure 18 compares the impulse response graphs of the SVAR model with Divisia Money (left panel), simple-sum M1 (middle panel) and simple-sum M3 (right panel). A percentage point increase in interest rate causes approximately 1.5% appreciation of pound vis-à-vis US dollar for the model with Divisia money. We observe similar result for the model that takes up simple sum M3. The response of exchange rate (impact appreciation and depreciation afterwards) to the monetary policy shock holds significant in all the three cases. However the response of the exchange rate is more pronounced in the model containing simple sum M1. The model with Divisia money shows that money demand drops significantly by 0.06% on impact and thereafter permanent decline following the policy shock. The model with simple sum M1 exhibit liquidity puzzle wherein the

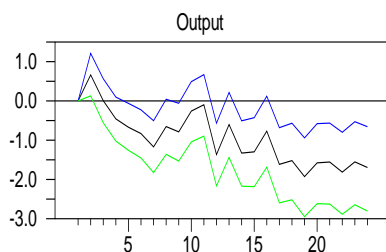
money demand increases with a rise in interest rates. The model with simple sum M3, though gives correct point responses of money, however, the responses remain insignificant throughout.

The prices show correct response with the inflation rate staying below zero for the first 10 months, following the monetary policy tightening. The rate of inflation falls by 0.03% approximately in the left panel (model with Divisia money) compared to 0.24% in the right panel (model with simple sum M3). But the middle panel (model with simple sum M1) exhibits price puzzle after the monetary policy response. Finally a contractionary monetary policy can affect output adversely causing up to 17% reduction in output, as captured in the model with Divisia money. Monetary policy shock seems to have a long-lasting impact on the industrial production extending close to 20 months. The industrial production shows positive response with a single peak on impact to a monetary policy shock. However, the industrial production begins to drop significantly in couple of months following the policy tightening. Therefore the response of exchange rate, money demand, output and prices are puzzle-free and in accordance with the theory, especially in the model with Divisia money.

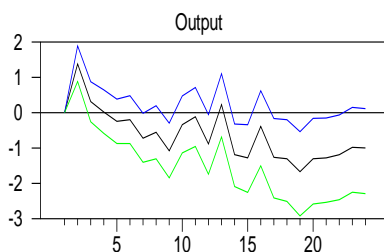
Figure 19: Impulse Responses to Monetary Policy Shock for UK

(Estimation Period 2001 Jan - 2015 May, Lags=13)

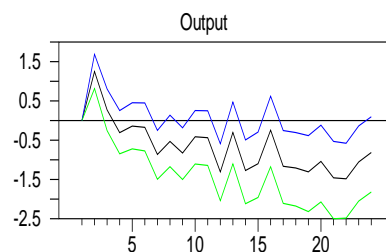
Model with Divisia Money

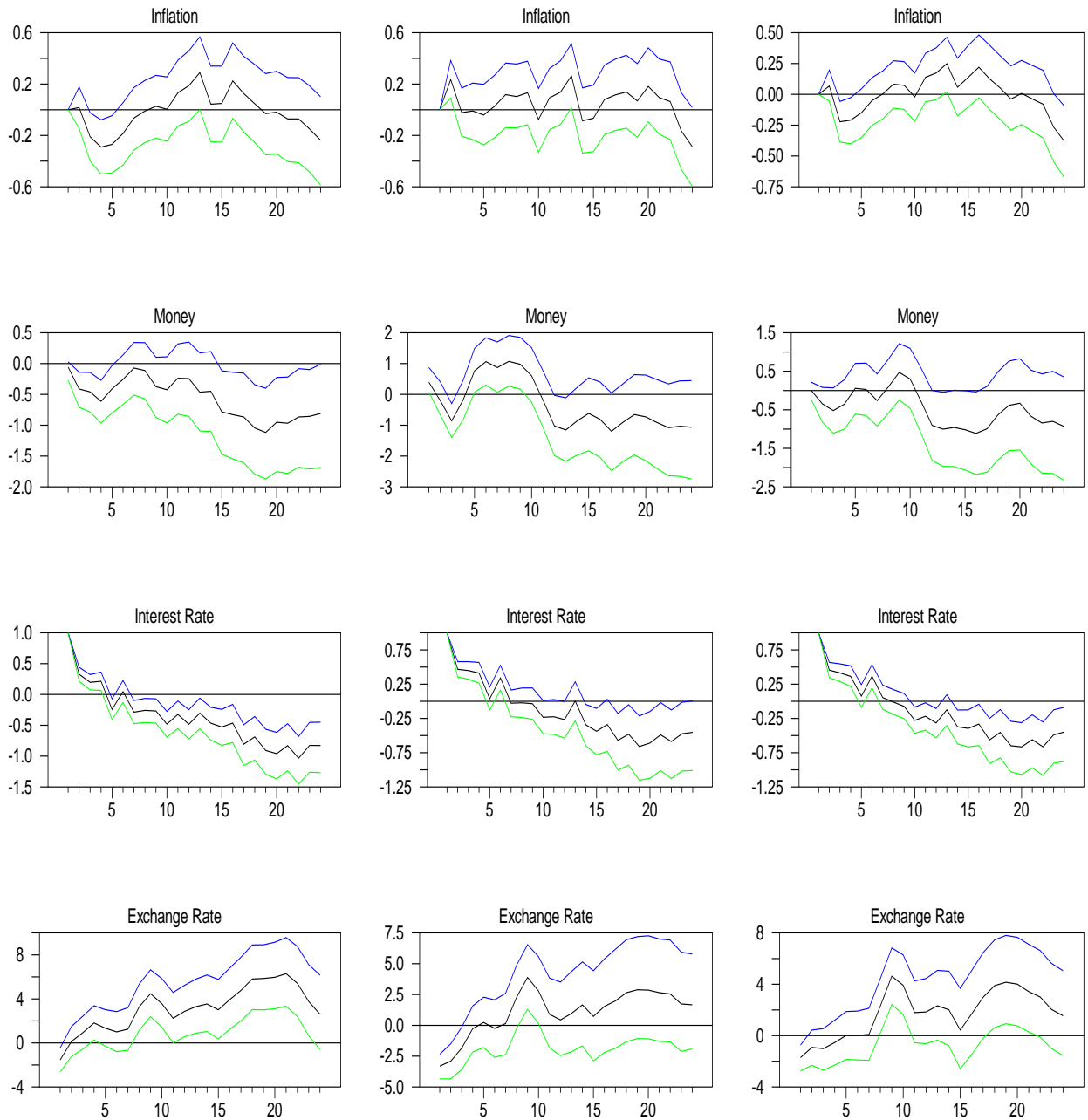


Model with M1 Money



Model with M3 Money



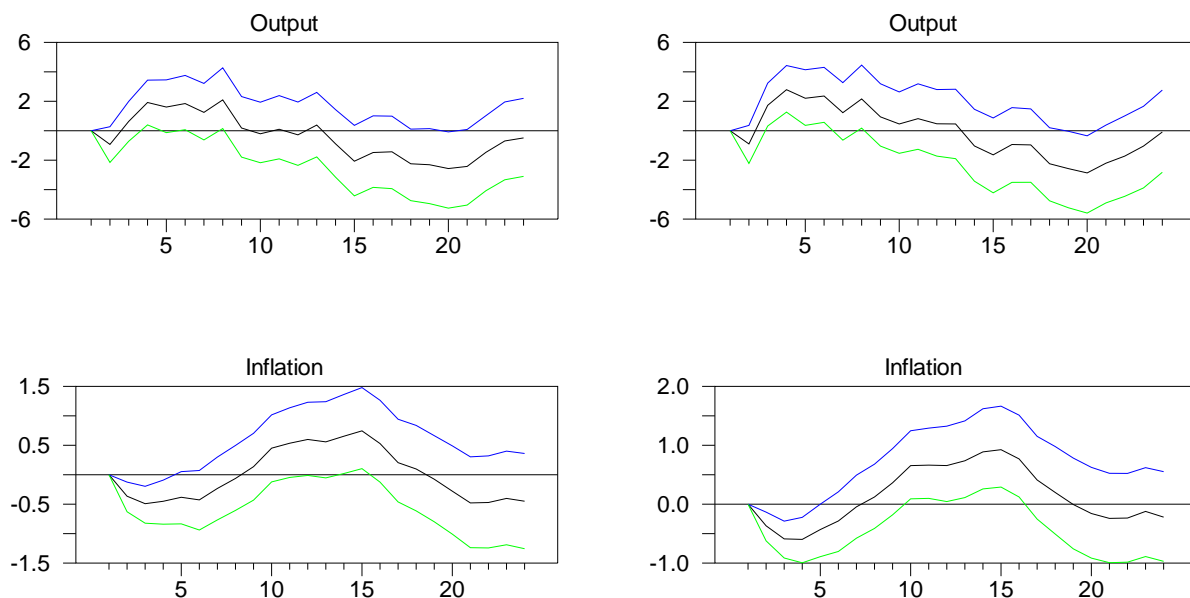


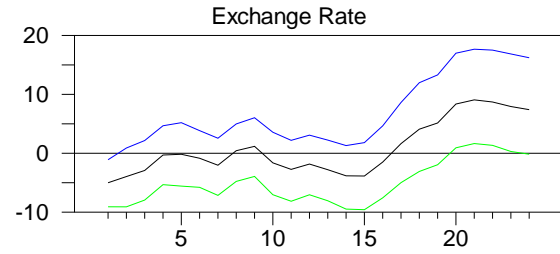
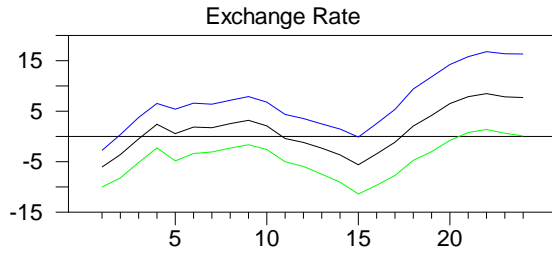
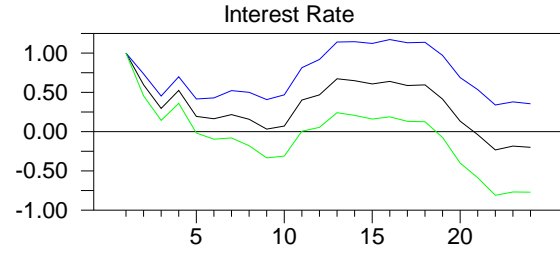
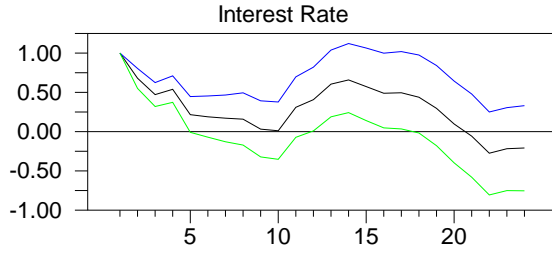
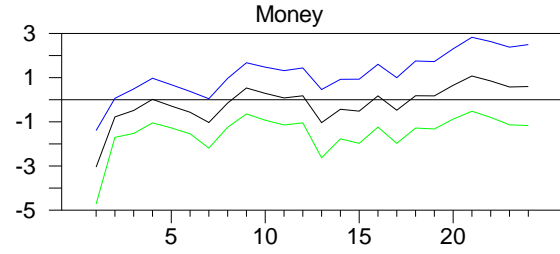
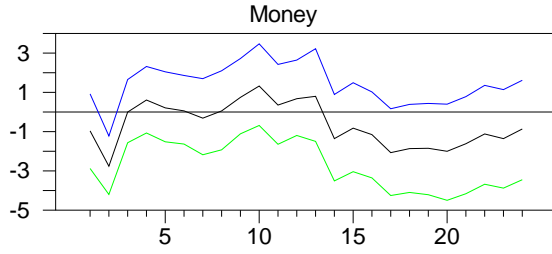
Poland: Figure 19 compares the impulse response graphs of the SVAR model with Divisia M3 (left panel) and simple sum M3 (right panel) for Poland. A percentage point increase in interest rate causes approximately 6% appreciation of Polish Zloty vis-à-vis US dollar for Divisia model as compared to

4.5% appreciation in the model with simple sum M3. We observe impact-appreciation of the exchange rate to a monetary policy shock, followed by mild yet significant depreciation in the left panel. A percentage rise in interest rate causes money demand to fall significantly with short-lasting impact. The prices show correct response with the inflation rate staying below zero for the first 8 months after monetary policy tightening. Following the contractionary monetary policy shock inflation temporarily falls by 0.05%. Finally a restrictive monetary policy exhibit negligible effect on output for models with Divisia money, but, the right panel records a significant rise in output from 2nd month to the 8th month showing output puzzle. Therefore the responses of exchange rate, money demand and prices to the monetary tightening are puzzle-free, precise in terms of tighter error bands and in accordance with the theory especially in the model with Divisia M3.

Figure 20: Impulse Responses to Monetary Policy Shock for POLAND

(Estimation Period: Dec 2001-June 2015, lags=13)





3.4.2 Variance Decomposition

The variance decomposition of the exchange rate to monetary policy shock is evaluated in table 14.

The model results with the different monetary aggregates simple sum M3, Divisia M3, Divisia M2 and Divisia L1 are presented for **India**. For the model with simple sum M3, monetary policy shock explain 8% of exchange rate variation in the 1st month, increasing to 10 % in the 4th month and 9% in the 8th month. After which the contribution of monetary policy shocks gradually declines. Generally, models with Divisia money perform relatively better, in terms of the monetary policy contributing more at each step in the future horizon. For example, the monetary policy in the model with Divisia M3 explains 14 % of exchange rate variation at the 1st month, increasing to 16% at the

4th month with a gradual decline afterwards. Also when we compare the relative performance of the model with Divisia money, at different level of aggregation, Divisia M2 seems to do the best in terms of explaining the exchange rate fluctuations.

For **United Kingdom**, the variance decomposition of the exchange rate to the monetary policy shock is evaluated in table 14. The performance of the model with different monetary aggregates namely, simple sum M1, simple sum M3 and a narrow Divisia measure is presented in the table below. For the model with simple sum M3, monetary policy shock explain 4% of exchange rate variation in the 1st month, decreasing to 2 % in the subsequent period and then slightly increasing afterward to 5 %. In comparison, models with Divisia money explain 4 % of exchange rate variation at the 1st month, 2% in the 2nd month and 4% in the 8th month, following a monetary policy shock, with the contribution significantly increasing as we move forward i.e. 16% in the 20th month and 18 % in the 24th month. Model with the Divisia monetary aggregate does relatively better than simple sum counterparts from 4th month onwards, in terms of explaining more of the exchange rate fluctuations. The variance decomposition analysis on the models with different monetary aggregates, simple sum M2, simple sum M3, Divisia M2 and Divisia M3 were also evaluated for **Poland**. For the model with simple sum M3, the monetary policy shock explain 4% of exchange rate variation in the 1st month, 2%, in the 4th month and 7% in the 24th month. In comparison, model with Divisia M3 explains 7% of exchange rate variation in the 1st month, 3% in the 4th month and 7% in the 24th month. Similarly the model with Divisia M2 performed relatively better than the model containing simple sum M2. Generally, model containing Divisia monetary aggregate performed relatively better than their simple sum counterpart.

Table 14: Variance Decomposition of Exchange Rate due to Monetary Policy Shocks								
Month	1	2	4	8	12	16	20	24
INDIA								
Model(M3)	8	8	10	9	7	6	6	5
Model(DivisiaM3)	14	14	16	14	12	11	10	8
Model(DivisiaM2)	17	18	21	15	13	12	11	9
Model(DivisiaL1)	14	15	16	14	12	12	11	8
UK								
Model(M1)	11	9	5	3	4	2	3	3
Model(M3)	4	2	2	2	5	3	5	5
Model(Divisia)	4	2	3	4	9	10	16	18
POLAND								
Model(M2)	5	3	2	2	2	2	3	8
Model(Divisia2)	7	4	3	3	3	4	4	7
Model(M3)	4	3	2	2	2	2	3	7
Model(Divisia3)	7	4	3	3	4	4	4	7

The variance decomposition of the exchange rate to the money demand shock is evaluated in table 15. The performance for models with different monetary aggregates, simple sum M3, Divisia M3, Divisia M2 and Divisia L1 are assessed for **India**. The variance decomposition analysis, following the money demand shock does not show significant difference in terms of the performance of the models between the simple sum and Divisia monetary aggregates. In fact, there is not much difference between the models containing Divisia monetary aggregates at different levels of

aggregation. The money demand shock by itself is unable to explain much of the variations in exchange rates. However the inclusion of the monetary aggregate may help the monetary policy shocks to explain more of the exchange rate dynamics as observed from the results in table 14. Hence, monetary aggregates act more like an informational variable instead of a causal variable, especially in explaining the exchange rate variation.

Table 15: Variance Decomposition of Exchange Rate due to Money Demand Shocks								
Month	1	2	4	8	12	16	20	24
INDIA								
Model(M3)	1	2	2	3	2	2	2	3
Model(DivisiaM3)	1	<1	1	2	2	3	4	3
Model(DivisiaM2)	<1	1	1	1	1	2	3	2
Model(DivisiaL1)	<1	<1	1	2	2	3	4	3
UK								
Model(M1)	2	1	1	2	1	1	1	1
Model(M3)	1	2	2	2	2	2	1	1
Model(Divisia)	1	1	2	10	12	13	15	17
POLAND								
Model(M2)	5	6	8	12	15	12	14	12
Model(Divisia2)	4	12	27	30	27	17	12	10
Model(M3)	4	4	7	11	15	12	12	11

For **United Kingdom**, models with different monetary aggregates simple sum M1, simple sum M3 and narrow Divisia measure are evaluated in table 15. The model with narrow Divisia does relatively better than the simple sum M1 and simple sum M3, in terms of money demand shocks explaining

fluctuations in the exchange rate, especially in the longer horizon. Therefore Divisia monetary aggregate, for United Kingdom acts as both informational variable and causal variable where in by itself explaining much of the exchange rate variations and also helping monetary policy explain fluctuation in the exchange rate.

For **Poland**, the variance decomposition of the exchange rate to money demand shock is evaluated and presented in table 15. The models with simple sum M3, simple sum M2 and its Divisia counterpart are presented below. When have tried to analyze the relative performance between the models Divisia monetary aggregate and its simple sum counterpart. Models with Divisia M2 does relatively better than their simple sum counterpart as the money demand shock explain a significant share of the exchange rate variations.

3.4.3 Forecast statistics for Exchange Rate

In this section, we calculate “out-of-sample” forecasts within the data range using Kalman filter to estimate the model using only the data up to the starting period of each set of forecasts. Notice that our purpose is not to fit the best forecasting model. Instead we try to evaluate (i) how the forecasting performance of the model change when we add money to the system and (ii) how the results vary with the different types of money. Forecast performance statistics (RMSE and Theil U) is compiled over the sample period and are given by the following formulas,

$$e_{it} = y_t - \hat{y}_{it} \quad (3.11)$$

Where \hat{y}_{it} is the forecast at step t from the i -th call and y_t is the actual value of the dependent variable.

Let N_t be the number of times that a forecast has been computed for horizon t , $i = 1, 2, \dots, N_t$.

$$\text{Root Mean Square Error: } RMSE_t = \sqrt{\sum_{i=1}^{N_t} e_{it}^2 / N_t} \quad (3.12)$$

Table 16 evaluates between the model with simple-sums and Divisia in terms of the RMSE statistic with the 24- step ahead forecasts. For **U.K.**, **Poland** and **India** we estimate the model through 2012:12, 2013:6 and 2006:6 respectively and updates for the period 2013:1 to 2014:12, 2013:7 to 2015:6, 2006:7 to 2008:6 respectively using the Kalman filter (24 steps) for **India**.

Table 16: Forecast Statistic Root Mean Square Error							
Steps	1	2	4	8	12	20	24
INDIA							
Model(DivisiaM3)	0.016817	0.02794	0.045093	0.08162	0.11592	0.130837	0.082902
Model(M3)	0.016819	0.027943	0.045097	0.081626	0.115927	0.130855	0.082923
UK							
Mod(No Money)	0.016	0.026	0.037	0.039	0.043	0.128	0.394
Model(M1)	0.016	0.025	0.038	0.068	0.106	0.193	0.235
Model(M3)	0.016	0.026	0.039	0.06	0.097	0.229	0.523
Model(N-Divisia)	0.014	0.022	0.027	0.022	0.034	0.015	0.045
POLAND							
Model(No Money)	2.45	3.84	7.65	14.56	16.92	21.52	19.35
Model(M1)	2.48	3.92	8	15.82	17.53	19.54	16.48
Model(Divisia1)	2.46	3.85	7.82	15.62	17.46	19.79	17.14
Model(M3)	2.46	3.84	7.51	13.97	16.68	20.43	18.2
Model(Divisia3)	2.42	3.7	7.4	14.47	16.65	20.72	18.66

Our basic interest is to compare across the models with no money, simple sum money and Divisia monetary aggregate. Our secondary set of interest is to compare models with monetary aggregates at different level of aggregation. For India, the RMSE for model with Divisia M3 and simple sum M3 is presented. Model with Divisia M3 shows forecast statistics (RMSE) which is lower than the model with simple sum M3 at every forecast horizon. When we compare RMSE for model with Narrow Divisia vs model with simple sum M3 money, it is 0.016817 vs 0.016819 1-step ahead, 0.02794 vs 0.027943 at 2-step ahead, 0.08162 vs 0.081626 in 4-step ahead and yet with a lower RMSE of 0.082902 compared to 0.082923 at 24-step ahead.

For U.K., table 16 compares the RMSE between the models with no money, model with simple sum M1, simple sum M3 and model with Divisia. We do not get any conclusive result in terms of RMSE when we compare between the models with no money and models with simple sum monetary aggregates where on some forecasting horizon, model with no money does better, and in some, the model with simple sum money does better. In fact, no money models, surprisingly does better in most of the forecast horizon, when compared to model with simple-sum M1 and M3. However, the model containing Divisia, performs better (in terms of registering lower RMSE value) than all other models at every forecast horizon. When we compare RMSE for model with Narrow Divisia vs model with simple sum money, it is 0.014 vs 0.016 at 1-step ahead, 0.022 vs 0.026 at 2-step ahead, 0.022 vs 0.06 in 4- step ahead and yet with a lower RMSE of 0.045 compared to 0.523 at 24-step ahead.

The forecast statistics, RMSE is also presented for Poland in table 16. The performance of the models with no money, simple sum M1, simple sum M3 and their Divisia counterparts are presented. In general, model with Divisia M3 seems to perform the best, when compared across all other models. Surprisingly, model with no money is seen to be doing better than the model with money at some of the forecast horizons. Also for Poland, the models at the broader level of aggregation is seen to be

doing better. When we compare RMSE for model with no money vs model with simple sum M1 money, it is 2.45 vs 2.48 at 1-step ahead, 3.84 vs 3.92 at 2-step ahead, 16.92 vs 17.53 in 12- step ahead. That is model with only interest rate is doing better till the 12th step ahead in the future and only after that money start playing informative role in exchange rate forecast with RMSE values of 19.54 and 16.48 in the 16th and 24th step in to the future compared to no money model whose respective RMSE values are 21.52 and 19.35. However, if we compare the model with Divisia M3 with model with simple sum M3 or model with no money, model with Divisia M3 has lower RMSE at every forecast horizon. 1st step, 2nd step, 8th step or 24 th step ahead in the future, the RMSE values for model with Divisia are 2.42, 3.7, 14.47 and 18.66 compared to model with simple sum M3, whose RMSE are 2.46, 3.84, 13.97 and 18.2 respectively or compared to model with no money whose RMSE are 2.45, 3.84, 14.56 and 19.35 respectively.

The forecast graphs are obtained through Gibbs Sampling on a Bayesian VAR with a “Minnesota” prior. The sequential likelihood ratio test selects 13 lags for India, UK and Poland for the estimation period. We hold back a part of the data to use for evaluating forecast performance. The graph forecasts 24 steps ahead with a +/- two standard error band using 2500 draws. The out of the sample simulations accounts for all uncertainty in forecasts: both the uncertainty regarding the coefficients (handled by Gibbs sampling) and the shocks during the forecast period (see Doan, 2012).

Figure 20 represents the out of sample forecasting graph for India and compares between the model with simple-sum M3 and model with the Divisia M3. The model forecast with Divisia M3 (represented in coral) stays closer to the actual LER value (represented in black). The model forecast with simple-sum M3 (represented in blue) diverges from actual value over time. The forecast band for the model with Divisia M3 (represented in pink) is narrower compared to forecast band for the

model with simple-sum M3 (represented in green), for the forecast horizon. This indicates a higher forecast accuracy in models with Divisia money compared to models with simple sum money.

Figure 21 represents the out of sample forecasting graph for U.K. and compares between the model with M1 money and model with the narrow Divisia. The model forecast with Divisia (represented in coral) stays closer to the actual log of exchange rate (LER) value (represented in black). The model forecast with M1 money is represented in blue, which diverges from actual value over time. The forecast bands for the model with Divisia (represented in pink) is relatively narrower compared to the forecast band for the model with M1 money (represented in green) atleast in the first few subsequent steps in the forecast horizon. The narrower bands imply that model with Divisia can predict the exchange rate with greater precision.

Figure 21: Out of Sample Forecast Graph for India

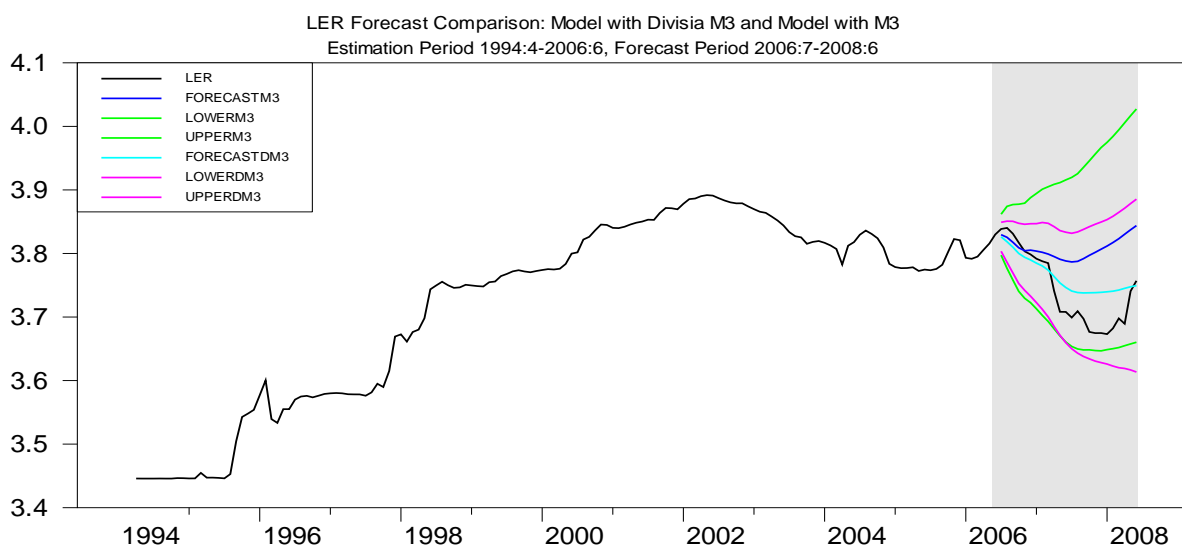


Figure 22: Out of Sample Forecast Graph for UK

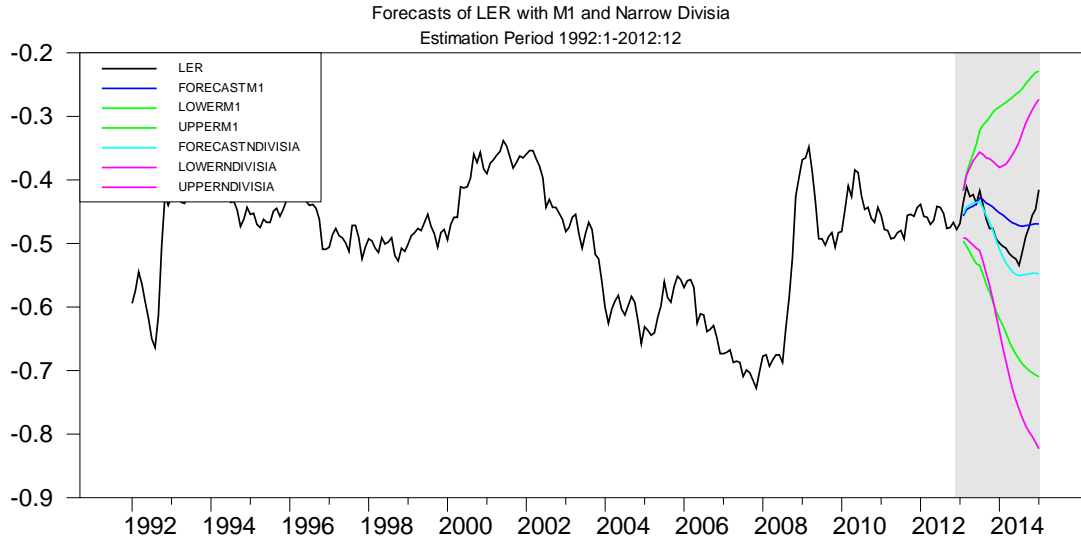
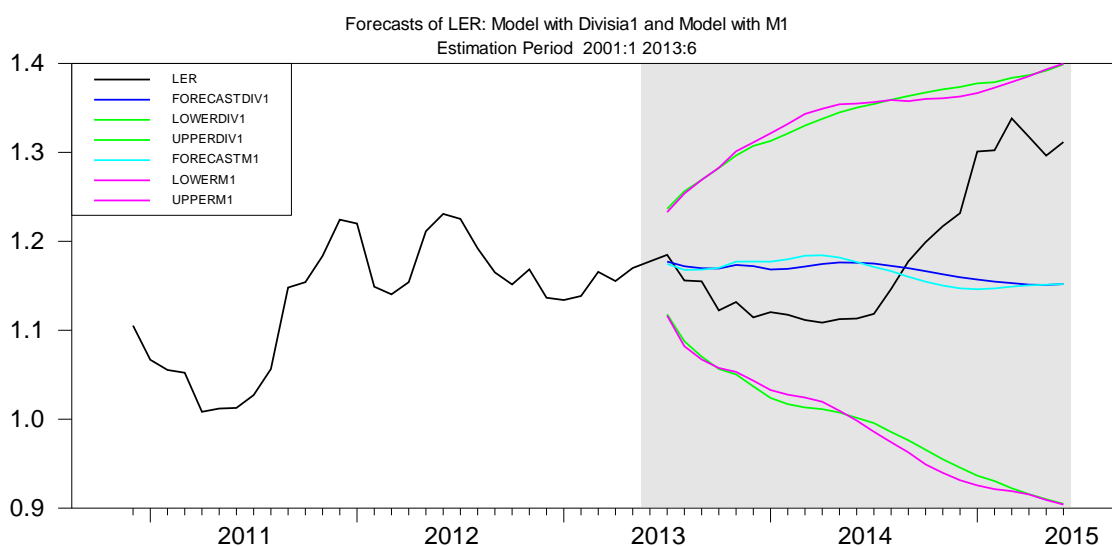


Figure 22 represents the out of sample forecasting graph for Poland and compares between the model with simple-sum M1 and model with the Divisia M1. The model forecast with Divisia M1 (represented in blue) and the model forecast with simple sum M1 (represented in coral) and the actual LER value (represented in black). The model forecast with the Divisia M1 does slightly better than the simple sum M1 over time. When the actual exchange rate was falling during 2013-2014, the point forecast of exchange rate from the model with Divisia was lower than the point forecast with the model with simple sum and closer to the actual exchange rate. Similarly, when exchange rate was going up in the latter months of 2014, the point forecast of exchange rate from Divisia models were above the point forecast from their simple sum counter-part. Hence model with Divisia money help

forecast exchange rate with greater accuracy. The forecast band for the model with Divisia M1 is represented in green and the forecast band for the model with simple-sum M1 is represented in pink.

Figure 23: Out of Sample Forecast Graph for Poland



We have evaluated the relative performance of models using the out-of-sample forecasting graphs and RMSE, Theil U statistic. We conclude that model with Divisia M3 does better than model with simple-sum M3 and model with no money in forecasting exchange rates both in short-run and long-run. Moreover, this results holds robust to different forms of Divisia money available

3.5 Conclusion

In this paper, we revisit the questions on monetary policy, the exchange rate puzzle, the inflationary puzzle, and monetary transmission mechanism for Poland, India and United Kingdom (U.K.). A Bayesian SVAR model similar to the K&R kind of restrictions is used to identify the money supply and money demand in the model. The paper is able to correctly identify monetary policy for Poland, India and UK and eliminate some of the persistent empirical puzzles that have been prevalent in the

exchange rate literature. Additionally, a superior form of the monetary measure called the Divisia monetary aggregate originated by Barnett (1980) is used to compare its performance vis-à-vis the simple sum money. The comparative analysis was needed at a time when the role of money has been increasingly de-emphasized in macroeconomic models. Leeper and Roush (2003) rightly point out that the liquidity effect and the impact of the rate cuts on the macroeconomic variables, depend on how we capture the role of money in the model. In other words, capturing the interaction between the Central Bank's reaction to economic condition and the private sector's response to policy action is important. Subsequently in this paper, we evaluate the role of monetary aggregates in exchange rates determination. We have compared between the models with simple-sum monetary aggregate and Divisia monetary aggregate, at different levels of aggregation. (Divisia M1, Divisia M2, Divisia M3 for Poland; DL1, DM2, DM3 for India; Index of monetary financial institutions, sterling Divisia for U.K.). Toda-Yamamoto Granger causality, Impulse response, variance decomposition and out-of-sample forecasting analysis were done to compare across the models with simple-sum monetary aggregate and Divisia money. In general, models with Divisia money did fairly better than model compared to simple-sum counterpart. The results in this paper confirm the finding that the information content in the monetary aggregates especially Divisia money is critical for monetary policy analysis.

References

- Anderson, R. G. and K. A. Kavajecz, 1994. "A Historical Perspective on the Federal Reserve's Monetary Aggregates: Definition, Construction, and Targeting," *Federal Bank of St. Louis Review* 76, 1-31.
- Assenmacher-Wesche, K. and S. Gerlach, 2006. "Interpreting Euro Area Inflation at High and Low frequencies." Bureau of International Settlement Working Paper, n. 195.
- Barnett, W. A. and A. Serletis, 2000. *The Theory of Monetary Aggregation*, Elsevier, Amsterdam
- Barnett, W. A. and Chauvet M., 2011. *Financial Aggregation and Index Number Theory*, World Scientific, Singapore.
- Barnett, W. A., 1980. Economic Monetary Aggregate: An Application of Index Number and Aggregation Theory. *Journal of Econometrics*, September, 1980
- Barnett, W. A., 2012. *Getting It Wrong: How Faulty Monetary Statistics Undermine the Fed, the Financial System, and the Economy*, MIT Press, Cambridge, MA.
- Barnett, W. A., Chauvet, M., and D. Leiva-Leon, 2015. "Real-Time Nowcasting of Nominal GDP Under Structural Break," *Journal of Econometrics*, forthcoming.
- Barnett, W. A., Liu, J., Mattson, R. S., and van den Noort, J. (2013), "The New CFS Divisia Monetary Aggregates: Design, Construction, and Data Sources," *Open Economies Review*, 24, 101–124. [257,261,262]
- Barnett, W. A. and Chang Ho Kwag, 2006. Exchange Rate Determination from Monetary Fundamentals: an Aggregation Theoretic Approach, *Frontiers in Finance and Economics* 3, n. 1, 29-48.
- Barnett, W. A., 1980. Economic Monetary Aggregate: An Application of Index Number and Aggregation Theory. *Journal of Econometrics* 14, September, 11-48.

- Belongia, M. (editor) and Binner, J. (editor), 2001. *Divisia Monetary Aggregates: Theory and Practice*, Palgrave Macmillan (January 6, 2001)
- Belongia, M. and P. Ireland, 2012. “Quantitative Easing: Interest Rates and Money in the Measurement of Monetary Policy.” Boston College Working Paper.
- Bernanke, B., 1986. “Alternative Explanations of Money Income Correlation.” In: Brunner, K. and A. H. Meltzer (Eds.), *Real Business Cycles, Real Exchange Rates, and Actual Policies*, Carnegie-Rochester Series on Public Policy 25, North Holland, Amsterdam, 49-99.
- Bjornland, H. C., 2009. Monetary policy and Exchange rate overshooting: Dornbusch was right after all, *Journal of International Economics* 79 64-77
- Blanchard, O. J. and Quah, D., 1989. The Dynamic Effects of Aggregate Demand and Supply Disturbances, *American Economic Review*, Vol. 79, pp. 655-673
- Brischetto, A. and G.Voss, 1999. “A Structural Vector Autoregression Model of Monetary Policy in Australia”. Research Discussion Paper 1999-11, Reserve Bank of Australia.
- Bruggeman, A, Camba-Mendez., G, Fischer, B, and J. Sousa, 2005. “Structural Filters for Monetary Analysis: the Inflationary Movements of Money in the Euro Area,” ECB Working Paper, n. 470.
- Carlo A. Favero; Massimiliano Marcellino. Modelling and Forecasting Fiscal Variables for the Euro Area, “Oxford Bulletin of Economics and Statistics, Department of Economics, University of Oxford, vol. 67(s1), pp. 755-783, December, 2005.
- Christiano, L. J., R. Motto, M. Rostagno, 2007. Two reasons why money and credit may be useful in monetary policy. NBER Working Paper, n 13502
- Christopher A. Sims. Interpreting the Macroeconomic Time Series Facts: The effects of Monetary Policy, Cowles Foundation Discussion Paper No. 1011, 1992.

- Chrystal, K. and R. MacDonald, 1995. "Exchange Rates, Financial Innovation and Divisia Money: the Sterling/Dollar Rate," *Journal of International Money and Finance* 14, 493-513.
- Cochrane, J. H, 2007. "Inflation Determination with Taylor Rules: a Critical Review," NBER Working Paper, n. 13409.
- Courtenay, S. and D. Thornton, 1987. "Solving the 1980s' Velocity Puzzle: A Progress Report," *St. Louis Federal Reserve Review* (August/September 1987), 175-204
- Cushman, David O.; Zha Tao. Identifying monetary policy in a small open economy under flexible exchange rates, *Journal of Monetary Economics*, 1997, Vol.39 (3), pp. 433-448.
- Devereaux, Michael B. Growth and the Dynamics of Endogenous Trade Liberalization, *Journal of Economic Dynamics and Control*, 23, 773-795
- Diewert, W., 1976. "Exact and Superlative Index Numbers," *Journal of Econometrics* 4, 115-145.
- Doan T., 2012, *RATS Handbook for Bayesian Econometrics*, Estima, Evanston, IL.
- Doan, T., 2013, *RATS Manual*, Version 8.3, Estima, Evanston, IL
- Dornbusch, R., 1976. Expectations and Exchange Rate Dynamics. *Journal of Political Economy* 84, 1161-1176.
- Dornbusch, Rudiger; Krugman, Paul. Flexible Exchange Rates in the Short Run. *Brookings Papers on Economic Activity*, 1976, Issue 3, pp. 537-584.
- Drake, L. and T. C. Mills, 2005. "A New Empirically Weighted Monetary Aggregate for the United States," *Economic Inquiry* 43, No.1, 138-157.
- Dua, P., Ranjan, R., 2011. Modelling and Forecasting the Indian Re/US dollar Exchange Rate. Working paper 197, Centre for Development Economics, Delhi School of Economics.
- Eichenbaum, Martin; Evans, Charles L. Some Empirical Evidence on the Effects of shocks to Monetary Policy on Exchange Rate, *The Quarterly Journal of Economics*, 1 November 1995, Vol.

110(4), pp.975-1009.

Gert Peersman, Frank Smets. The Industry Effects of Monetary Policy in the Euro Area, *Economic Journal*, Royal Economic Society, vol. 115(503), pp. 319-342, 2004.

Goodfriend, M. and M. J. Lacker, 1999. "Limited Commitment and Central Bank Lending," *Economic Quarterly* - Federal Reserve Bank of Richmond, Fall, 1-27.

Grilli, Vittorio; Roubini, Nouriel. Liquidity models in open economies: Theory and empirical evidence, *European Economic Review*, Elsevier, vol. 40(3-5), pp. 847-859, April, 1996.

Hamilton, J. D. (1994), *Time Series Econometrics*, Princeton U. Press, Princeton, NJ.

Hendrickson, J. R., 2014. Redundancy and Mismeasurement? A Reappraisal of Money. *Macroeconomic Dynamics*, 18, 2014, 1437–1465.

Ireland, P., 2001a. "Sticky-Price Models of the Business Cycle - Specification and Stability," *Journal of Monetary Economics* 47, 3-18.

Ireland, P., 2001b. "Money's Role in the Monetary Business Cycle," Working Paper 8115, National Bureau of Economic Research.

Jaaskela Jarkko; Nimark Kristoffer. A Medium-scale New Keynesian Open Economy Model of Australia. IDEAS Working Paper Series from RePec, 2011.

Jan Kakes. Monetary transmission in Europe: the role of financial markets and credit. Chettenham, U.K.; Northampton, MA: E. Elgar, 1968-; c2000.

Jansen, E. S., 2004. "Modelling Inflation in Euro Area," ECB Working Paper, n. 322.

Jeremy Lawson, Daniel Rees. A Sectoral Model of the Australian Economy, RBA Research Discussion Paper rdp 2008-01, Reserve Bank of Australia.

Kim, S. and N. Roubini, 2000. "Exchange Rate Anomalies in the Industrial Countries: A Solution with a Structural VAR Approach," *Journal of Monetary Economics* 45(3), pp. 561-586.

- Kim, S., 2005, Monetary Policy, Foreign Exchange Rate Policy, Delayed Overshooting. *Journal of Money, Credit and Banking*, Vol.37, No.4, August, 2005
- Leeper, E. and J. Roush, 2003. "Putting 'M' Back in Monetary Policy," *Journal of Money, Credit and Banking* 35, No.6, pp. 1217-1256.
- Linde, Jesper. Monetary Policy Shocks and Business Cycle Fluctuations in Small Open Economy: Sweden 1986-2002, Working Paper Series 153, Sveriges Riksbank (Central Bank of Sweden), 2003
- Litterman, R. B., Weiss, L. M., 1985. Money, Real Interest Rates, and Output: A Reinterpretation of Postwar U.S. Data, *Econometrica*, Econometric Society, vol. 53(1), pages 129-56, January.
- M.M.G. Fase; C.C.A. Winder. Wealth and the demand for money: empirical evidence for the Netherland and Belgium, Amsterdam: De Nederlandsche Bank, 1997
- Marion Kohler, Josef Manalo, Dilhan Perera. Exchange Rate Movements and Economic Activity, *Bulletin*, March, Quarter, 2014.
- Masuch, K. S., Nicoletti-Altimari, S, and M. Rostagno, 2003. "The Role of Money in Monetary Policy Making," Bureau of International Settlement Working Paper, n 1
- Michael T. Belongia & Peter N. Ireland (2015) Interest Rates and Money in the Measurement of Monetary Policy, *Journal of Business & Economic Statistics*, 33:2, 255-269, DOI: 10.1080/07350015.2014.946132
- Mojon, Benoit; Peersman, Gert,. A VAR description of the effects of monetary policy in the individual countries of the euro area. Working Paper Series 0092, European Central Bank, 2003.
- Nelson, E, 2003. "The Future of Monetary Aggregates in Monetary Policy Analysis," *Journal of Monetary Economics* vol. 50(5), 1029-1059.
- Nicoletti-Altimari, S, 2001. "Does Money Lead Inflation in Euro Area?" ECB Working Paper, n. 63.

- Ramachandran, M, Das, R., and B. Bhoi, 2010. "The Divisia Monetary Indices as Leading Indicators of Inflation," Reserve Bank of India Development Research Group Study No.36, Mumbai.
- Ramachandran, M., R. Das, B. Bhoi. 2010, The Divisia Monetary Indices as Leading Indicators of Inflation, Reserve Bank of India Development Research Group Study No.36, Mumbai
- Rotemberg, J.J., M. Woodford, 1999. Interest Rate Rules in an Estimated Sticky Price Model in Monetary Policy Rules, ed. J.B. Taylor, pp. 57-119. University of Chicago Press, Chicago.
- Schunk, D., 2001. "The Relative Forecasting Performance of the Divisia and Simple Sum Monetary Aggregate," *Journal of Money, Credit and Banking* 33, 272-283.
- Serletis, A. and K.Istiak, 2015. "Are the Responses of the U.S. Economy Asymmetric to Positive and Negative Money Supply Shocks?" *Open Economies Review*, forthcoming.
- Serletis, A. and P. Gogas, 2014. "Divisia Monetary Aggregates, the Great Ratios, and Classical Money Demand Functions." *Journal of Money, Credit and Banking* 46, 229-241.
- Serletis, A. and S. Rahman, 2015. "On the Output Effects of Monetary Variability." *Open Economies Review* 26, 225-236
- Serletis, A. and S.Rahman, 2013. "The Case for Divisia Money Targeting." *Macroeconomic Dynamics* 17, 1638-1658.
- Sims, C. A., 1980, "Macroeconomics and Reality," *Econometrica* 48, 1-48.
- Sims, C. A., 1980. Comparison of Interwar and Postwar Business Cycles: Monetarism Reconsidered. American Economic Association, vol. 70(2), pages 250-57, May.
- Stock, J., M. Watson, 1999. Forecasting inflation. *Journal of Monetary Economics*, 44, 293-335
- Taylor, J., 1999. *Monetary Policy Rules*, University of Chicago Press, Chicago, IL.
- Toda, H.Y., Yamamoto. T., 1995. Statistical inference in vector autoregression with possibly integrated processes. *Journal of Econometrics*. 1995, vol. 66, issue 1-2, pages 225-250.

Trecoci, C. and J. L. Vega, 2002. “The Information Content of M3 for Future Inflation in Euro Area,” *Weltwirtschaftliches Archiv* 138 (1), 22-53.

Appendix

<u>Table A: Lag Selection Test</u>						
INDIA						
	(7 vs 6 Lags)		(6 vs 5 Lags)		(5 vs 4 Lags)	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Model (DM3)	38.49	0.86	73.66	0.01	57.88	0.18
Model (M3)	38.24	0.87	54.12	0.29	69.43	0.03
Model (DL1)	39.09	0.84	74.33	0.01	58.11	0.17
Model (DM2)	49.71	0.44	80.31	0.00	70.37	0.02
UK						
	(13 vs 12 lags)		(12 vs 11 lags)		(11 vs 10 lags)	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Model (M1)	94.17	0.00	86.43	0.00	53.51	0.31
Model (M3)	96.44	0.00	67.77	0.04	76.33	0.01
Model(Divisia)	84.86	0.00	76.54	0.01	69.00	0.03

POLAND						
	(14 vs 13 lags)		(13 vs 12 lags)		(12 vs 11 lags)	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Model (M1)	73.04	0.01	101.33	0.00	59.43	0.15
Model (M3)	65.66	0.06	112.11	0.00	76.33	0.01
Model(Div1)	79.60	0.00	104.24	0.00	60.91	0.12
Model(Div3)	68.02	0.04	111.96	0.00	68.02	0.04

Table B: Lag Selection Test						
Model	Test for 4 vs 3 Lags		Test for 3 vs 2 Lags		Test for 2 vs 1 Lags	
	χ^2	Significance Level	χ^2	Significance Level	χ^2	Significance Level
Australia	59.359463	0.00843706	62.569388	0.00393780	82.284179	0.00001756
New Zealand	46.908913	0.10534968	5.115376	0.00209364	80.518748	0.00002976
Sweden	25.022475	0.91531275	58.310605	0.01072710	58.227758	0.01093040
Canada	42.228934	0.21971191	36.390126	0.45049484	80.204840	0.00003266

Table C: Largest Root in the SVAR model	
Australia	0.89844
New Zealand	0.88416
Sweden	0.87439
Canada	0.81911

Table D: Lag Selection Test						
Model	Test for 7 vs 6 Lags		Test 6 vs 5 Lags		Test 5 vs 4 Lags	
	χ^2	Significance	χ^2	Significance	χ^2	Significance
		Level		Level		Level
Model 1	38.488243	0.85999185	73.662305	0.01288129	57.877533	0.18031970
Model 2	38.238935	0.86648886	54.117803	0.28541031	69.431849	0.02893017
Model 3	53.002955	0.32246811	78.648694	0.00456914	64.755425	0.06514492
Model 4	39.090622	0.84354759	74.325737	0.01127813	58.111194	0.17483359
Model 5	49.714073	0.44468077	80.313435	0.00317348	70.370490	0.02431895
Model 6	44.884835	0.64059402	76.544547	0.00714969	52.272749	0.34806341
Model 7	34.424993	0.94307877	60.173485	0.13157340	67.103896	0.04383014
Model 8	55.083386	0.25542317	83.970999	0.00138233	60.157528	0.13187352
Model 9	45.679504	0.60854031	76.434126	0.00731667	52.450227	0.34175099
Model10	53.620973	0.30161218	82.322186	0.00202066	65.886271	0.05398571